Evaluation of Pavement Markings on Challenging Surfaces

Minnesota Department of Transportation

RESEARCH SERVICES & LIBRARY

Office of Transportation System Management

Neal Hawkins, Principal Investigator
Institute for Transportation
Iowa State University

March 2016

Research Project
Final Report 2016-08

To request this document in an alternative format call 651-366-4718 or 1-800-657-3774 (Greater Minnesota) or email your request to ADArequest.dot@state.mn.us. Please request at least one week in advance.

Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.
MN/RC 2016-08		

4. Title and Subtitle	5. Report Date
Evaluation of Pavement Markings on Challenging Surfaces	March 2016
	6.
7. Author(s)	8. Performing Organization Report No.
Neal Hawkins, Omar Smadi, and Skylar Knickerbocker	
9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
Institute for Transportation Iowa State University 2711 S. Loop Drive, Suite 4700 Ames, Iowa 50011-8664	11. Contract (C) or Grant (G) No. (C) 99004 (wo) 2
12. Sponsoring Organization Name and Address	13. Type of Report and Period Covered
Minnesota Department of Transportation Research Services & Library 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

http://www.lrrb.org/pdf/201608.pdf

16. Abstract (Limit: 250 words)

The objective of this research was to conduct a field trial to evaluate the marking performance of different combinations of pavement marking materials and installation practices on challenging surfaces. The trial included a range of pavement marking products over varied roadway characteristics to assess the performance of different marking materials over different challenging surfaces by product, thickness, bead package, and whether or not a primer was applied.

The research team worked with the technical advisory panel (TAP) to document pavement marking performance on several municipal roadways within the city of Eden Prairie and to organize and prepare for field testing of different marking materials on both a seal coat and micro surface roadway. These projects provide pavement marking performance on challenging surfaces information over different conditions (traffic levels and line types) apart from the MnDOT research test deck scenarios.

These results provide MnDOT with a basis to consider pavement marking striping practices on challenging surfaces in terms of performance and cost. The high-build materials (primer plus VISILOK) and epoxies showed similar performance, which provides a good basis for material selection.

17. Document Analysis/Descriptors	18. Availability Statement
challenging surfaces, surfaces, micro surfacing, road marking materials, retroreflectivity, seal coats	No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	60	

Evaluation of Pavement Markings on Challenging Surfaces

Final Report

Prepared by:

Neal Hawkins
Omar Smadi
Skylar Knickerbocker
Institute for Transportation
Iowa State University

March 2016

Published by:

Minnesota Department of Transportation
Research Services & Library
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

Acknowledgments

The researchers would like to acknowledge the Minnesota Department of Transportation (MnDOT) for sponsoring this project. The authors also want to thank the MnDOT technical advisory panel (TAP) members for their input and insightful feedback throughout the project.

Table of Contents

List of Figures

List of Tables

Executive Summary

The objective of this research was to conduct a field trial to evaluate the marking performance of different combinations of pavement marking materials and installation practices on challenging surfaces. The trial included a range of pavement marking products over varied roadway characteristics.

Existing Practice

The research team worked with the technical advisory panel (TAP) to document pavement marking performance on several municipal roadways within the City of Eden Prairie. These projects provide pavement marking performance on challenging surfaces information over different conditions (traffic levels and line types) apart from the MnDOT research test deck scenarios. Seven different locations were measured, all of which were on seal-coated roadways that were installed in either 2012 or 2013. Based on these field measurements, the following conclusions can be made:

- For yellow centerlines, roadway sections initially painted with latex and epoxy the following year performed (using 100 mcd as a performance threshold) over at least two years and possibly three years, based on traffic and winter maintenance conditions.

- For white edgelines and white skip lines, the data show a difference in performance due to traffic. Section 3 (more than 19,000 vehicles per day) measured 132 mcd after one winter compared to Section 4 (4,400 vehicles per day), which measured 226 mcd. Even though the data are limited, epoxy (applied one year after latex) appears to perform for at least two years and possibly three, depending on traffic and winter maintenance.

- Starting in 2013, the city of Eden Prairie changed its striping practices so that it initially stripes seal-coated roadways with latex paint and then restripes a year later with epoxy. These findings support this practice and show that this can extend the performance of the epoxy stripe up to three years. In discussions with the city, we found that it was replacing epoxy striping after one year on this type of challenging surface.

Field Evaluation

The research team worked with the project TAP to organize and prepare for field testing of different marking materials on both a seal coat and micro surface roadway. The objective of the field evaluation was to assess the performance of different marking materials over different challenging surfaces by product, thickness, bead package, and whether or not a primer was applied.

The test decks were installed on US 61 and US 52 in August 2013. The US 61 test deck failed due to pavement material issues and was dropped after initial measurements. However, US 52 was measured over two winters. The US 52 evaluation provides the basis for the following conclusions.

- Latex (12 mil thickness) – The two latex sections installed (with and without primer) did not perform and had to be repainted in 2014 (less than one year of performance).

- High build paint – For the 25 mil thickness, the latex primer improved the performance of the pavement marking material. The average for white skip/edgelines was 98 mcd with a primer compared to 83 mcd without. When the material thickness was increased to 35 mil, the primer was not found to have an impact.

- Epoxy – The two epoxy materials used, HPS4 and MFUA-10 (both at 12 mil thickness), provided good performance after two winters regardless of whether a primer was used or not.

- Material thickness – Without the seal-coat test results for US 61, it is not possible to contrast the impact of marking material thicknesses based solely on the micro surface on US 52. However, there is evidence that an increased material thickness improves performance given the results of the 12 mil latex and 25 mil high build. When the material thickness increases above 25 mil, there appears to be enough material to cover the surface voids (resulting from a challenging surface) and still have good performance without a primer.

These results provide MnDOT with a basis to consider pavement marking striping practices on challenging surfaces in terms of performance and cost. The high-build materials (primer plus VISILOK) and epoxies showed similar performance, which provides a good basis for material selection.

Additional work should be completed to evaluate pavement marking performance on seal-coated surfaces given the distinct difference in the surface properties of seal coats versus micro surfacing.

Chapter 1. Introduction

The Minnesota Department of Transportation (MnDOT) has experienced poor pavement marking performance on “non-smooth” roadway surfaces such as seal coat and micro surface treated roadways, sometimes referred to as “challenging surface” roadways. This project builds on a previous project, Pavement Marking Compatibility with Chip Seal and Micro Surfacing, and provides a field evaluation of pavement marking products on MnDOT roadways. This information will support MnDOT operational practices across all districts and the development of technical memorandum guidance.

The project tasks are summarized in Table 1.

Table 1-1. Project by task number.

Task	Description
1A	Field Evaluation Characteristics
1B	Documentation of Existing Practices
2	Test Deck Installation
3A	2013 Measurement (Initial)
3B	2014 Measurement
3C	2015 Measurement
4	Draft Final Report
5	Final Report

1.1 Project Timeline

August 27, 2013

- Test deck layout - Measure, layout, and pre-mark each test deck (US 61 and US 52).
- Install Primer – The MnDOT Metro district latex truck was used to paint the primer sections on both roadways and for all applicable sections. The primer installation included M-247 glass beads per MnDOT direction (installed 24 hours prior to permanent stripe).
- Truck Calibration – Representatives from the paint manufacturer and bead vendors met with DOT staff in Wilson, MN to equip (pressure pot) and calibrate the Rochester latex truck (used for high build and VISILOK). The truck was calibrated to: 4.0 mph for 35 wet mils application and 5.5 mph for 25 wet mils.

August 28, 2013

- Install Pavement Markings – Staged in Hastings and began on US 61 followed by US 52. All truck/crew coordination by Central Striping (Brad Lechtenberg).

September 11, 2013

- Install HPS-4 Epoxy Pavement Markings – Due to a truck breakdown, the Epoxy markings (Section 4 for both roadways) were installed after the Labor Day holiday by the D1 crew.

October 9, 2013

- Measured retroreflectivity (initial) for all lines.

Spring 2014

- Advised that the seal coat surface installed on US 61 had failed due to unknown paving material issues. MnDOT subsequently eliminated the US 61 test deck from the study.

July 9, 2014

- Completed spring retroreflectivity measurements for US 52. Observed and confirmed that MnDOT had already re-striped the latex sections 1 and 2 due to poor presence, therefore these sections were not measured and will be eliminated from the study.

May 21, 2015

- Completed final measurement on US 52 (Task 3C)

August 17, 2015

- Completed measurements for challenging surfaced roadways identified by and within the City of Eden Prairie for Task 1B Existing practices.

Chapter 2. Field Evaluation Characteristics

The research team worked with the project technical advisory panel (TAP) to organize and prepare for the field installations. This included identifying the marking materials to be tested, the range of roadway characteristics to be included for testing, the application options considered, and the test deck locations and layout details. A brief description of each follows:

2.1 Pavement Marking Material Considerations

A range of potential pavement marking materials were considered and discussed with the project TAP. In addition, feedback was provided by other staff from both Metro district Central Striping. A number of pavement marking vendors provided advice and a willingness to support the field evaluation. The initial products considered were narrowed to MnDOT standards (Latex, HPS4, MFUA-10), as well as several thicknesses of High Build, Thermoplastic, and a specialized waterborne mixture called “Anti-Sag”.

2.2 Roadway Characteristics

When considering roadways for resurfacing, MnDOT typically selects a seal coat surface for lower volume roadways with minimum rutting. In contrast, micro surfacing is selected for higher volume roads and/or roadways with moderate rutting. In general, most of the seal coat projects are for two-lane roadways with micro surfacing typically applied to the four-lane roadway sections as illustrated in Figure 1.

Figure 2-1. Typical MnDOT Challenging Surface Treatments

Based on these conditions, the research team worked with district staff to identify seal coat and micro surface project locations (for the 2013 construction season) that would support the pavement marking evaluation.

Given a desire by the technical advisory panel (TAP) that the pavement marking evaluation be a part of a paving project, the final roadway selections were made by a subgroup consisting of the following members:

- Mitch Bartelt, MnDOT Central Office (CO) Traffic
- Paul Nolan, MnDOT Metro Maintenance
- Heather Gardner, MnDOT Metro Traffic
- Ken Johnson, MnDOT CO Traffic
- Michelle Moser, MnDOT CO Traffic
- Wayne Lindbloom, MnDOT Metro Maintenance
- Brad Lechtenberg, MnDOT CO Maintenance Striping
- Bruce Daniel, MnDOT CO Maintenance Striping
- Neal Hawkins, Center for Transportation Research and Education (CTRE) at Iowa State University (ISU)

These efforts resulted in the identification of three 2013 paving projects within the Metro district as noted in Table 2.

Table 2-1. Pavement marking evaluation locations.

Roadway/Location	Lanes, Surface Treatment	Location Details
US 52 from roughly Rosemount to Hampton	multilane, micro surfacing	From RP 115.6 (CSAH 42) to RP 101 (north of CSAH 86)
MN 3 north of Northfield	2-lane/2-way, micro surfacing	From south of TH 50 to CSAH 47, just north of Northfield. This is about 11 miles long.
US 61 south of Hastings	2-lane/2-way chip seal	From TH 316 (N junction) to TH 316 (S junction). This is 12 miles long. It also has a N-S section and an E-W section, if any comparison of the sort is desired.

A small segment, roughly 3 miles long, along each roadway would be used for the pavement marking evaluations. Figure 2 shows all of the projects considered with the final selections labelled 1, 4, and 7. Figure 3 provides a close-up view and construction beginning and ending points for these projects.

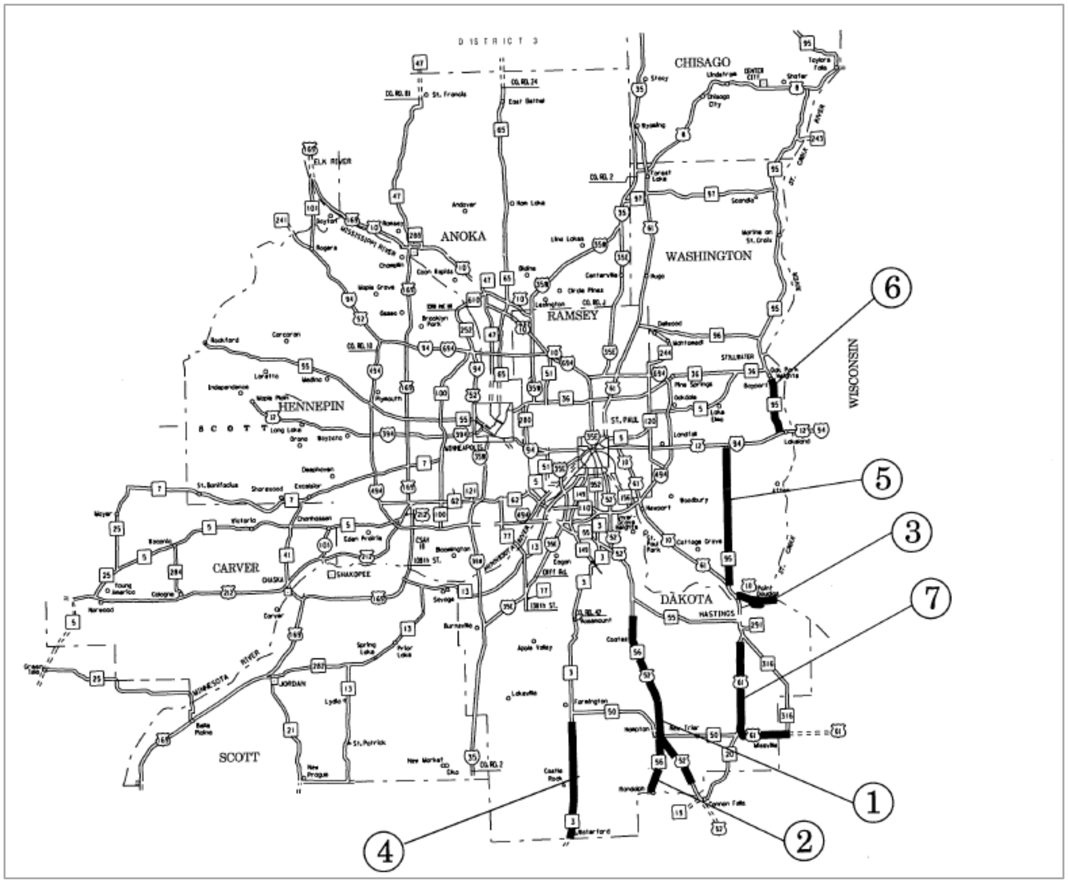


Figure 2-2. Area Map showing Paving Projects Considered

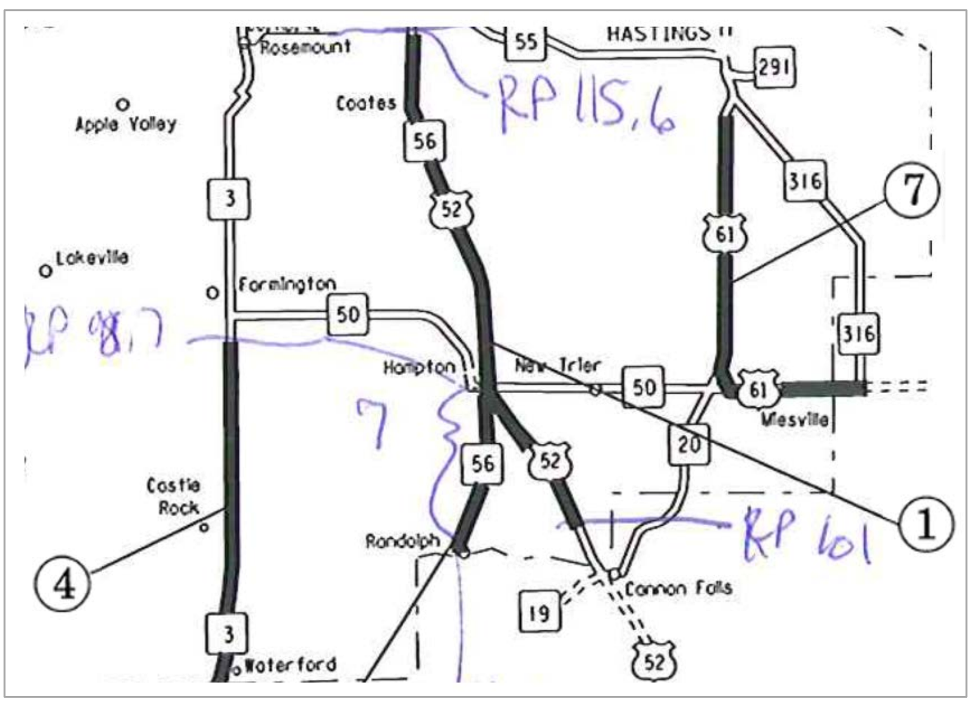


Figure 2-3. Begin/End Points for Paving Activities

2.3 Application Options

The course surface conditions for both seal coat and micro surfaced roadways have an impact on the ability to install markings at a sufficient thickness. This in-turn impacts marking performance, bead placement, and overall visibility. Given this, the research team and project TAP included an evaluation of marking products with and without a pavement marking "primer." The primer chosen was standard latex paint at a 15 mil wet thickness. The concept is illustrated in Figure 4.

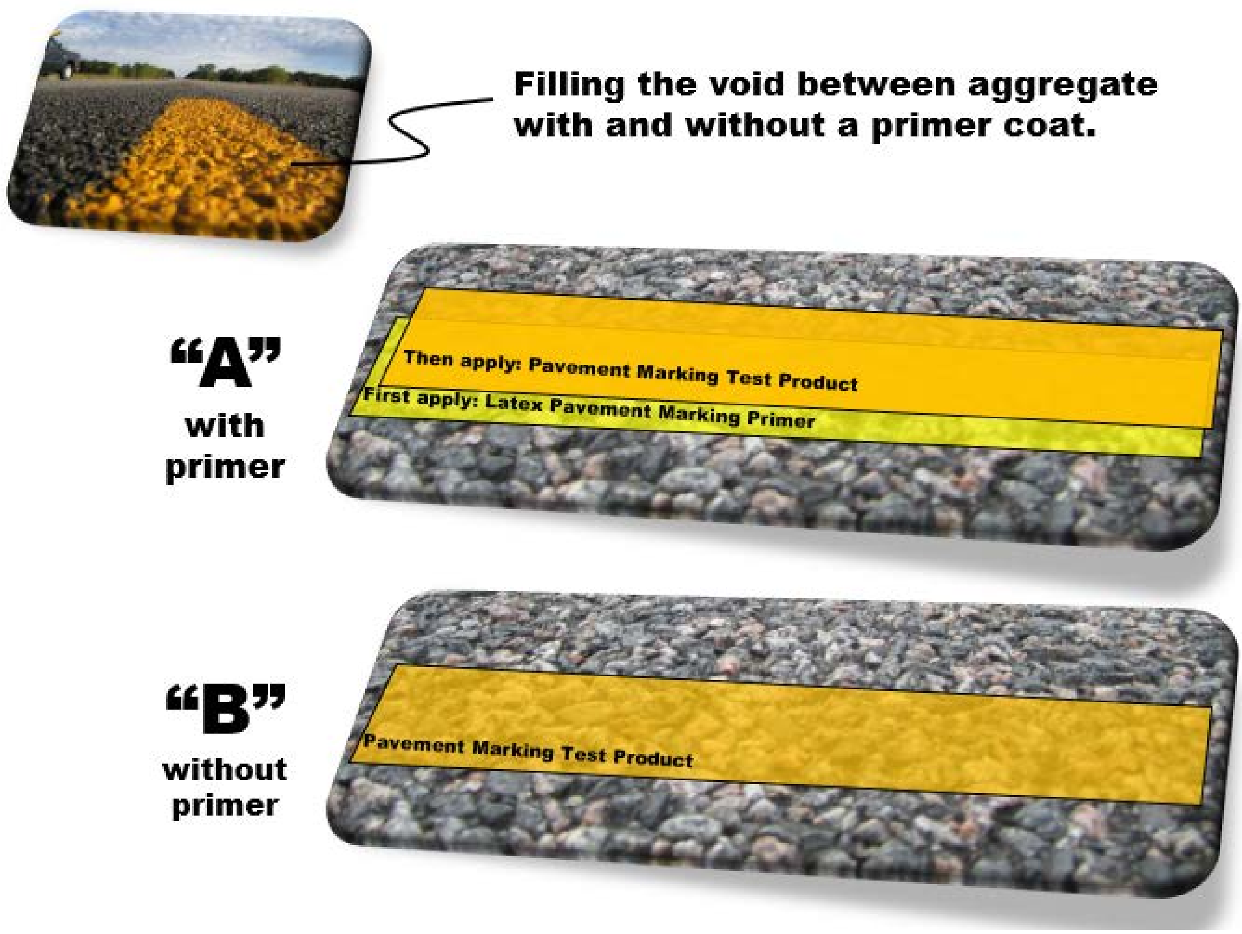


Figure 2-4. Evaluation Details for Pavement Marking Primer

2.4 Test Deck Layout and Revisions to the Evaluation Plan

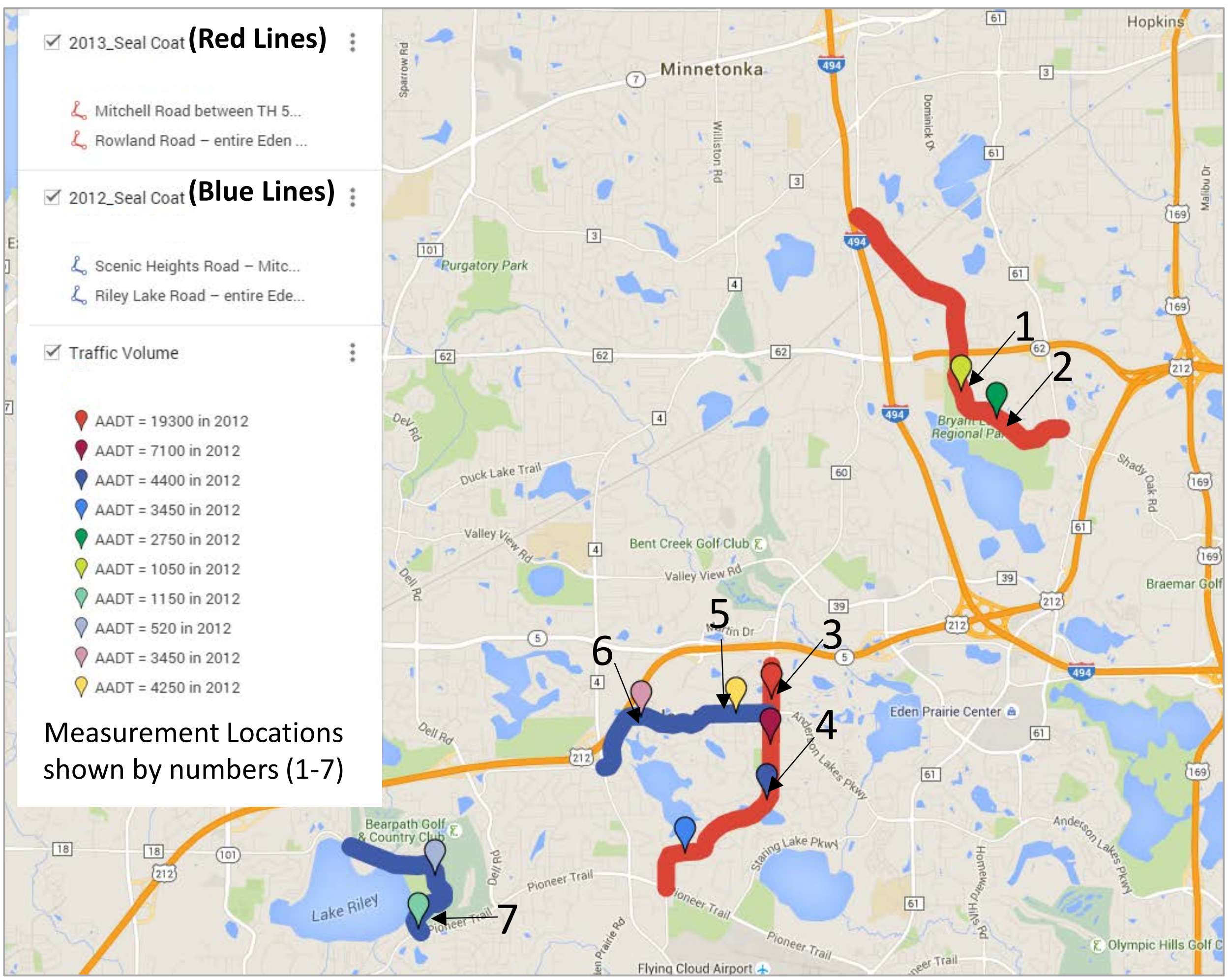
The research team worked with the project TAP to develop a draft evaluation plan, which would be applied to each roadway. This draft plan identified the test sections by number, subsection, length, whether or not a primer would be applied, the test marking material, material thickness, line types to be evaluated, and who the line would installed the line. The final evaluation plan is included in Chapter 4.

Chapter 3. Documentation of Existing Practices

The research team worked with the TAP to document pavement marking performance on several municipal roadways within the City of Eden Prairie. These projects provide pavement marking performance on challenging surfaces information over different conditions apart from the MnDOT research test deck scenarios. A summary of findings follows.

3.1 Site Selection

The City of Eden Prairie was asked to identify roadways that have had new challenging surfaces (seal coat or micro-surface) installed within the last several years. Once identified, the team traveled to each site to document the pavement marking performance on these roadways. The City noted that, starting in 2013, they changed their practice so that they initially stripe this type of road with latex paint and then restripe a year later with epoxy. A map showing each roadway, along with traffic count information and the locations measured are shown in Figure 5.



Source: "Eden Prairie, Minnesota." Map. Google Maps. ©Google 2015, August 17, 2015.

Figure 3-1. Eden Prairie Measurement Locations

The following two roadways were seal coated in 2013, had latex applied initially, and then were restriped in 2014 using epoxy paint:

- **Mitchell Road** between TH 5/212 and Pioneer Trail (CR 1) (measurement locations #3 and #4)
- **Rowland Road** – entire Eden Prairie length (measurement locations #1 and #2)

The following two roadways were seal coated in 2012, painted with epoxy in 2012, and have not been painted since:

- **Scenic Heights Road** – Mitchell Road to Eden Prairie Road (CR 4) [measurement locations #5 and #6]
- **Riley Lake Road** – entire Eden Prairie length (measurement location #7)

3.2 Field Measurements

The research team measured all four roadways on August 17, 2015. For each numbered location shown in Figure 5 (noted with 1 through 7), a series of 16 retroreflectivity measurements were taken per direction of travel over a roughly 400-foot section. All measurements were made using a hand-held LTL-X device, which was calibrated prior to the measurements. In addition, images were taken of the pavement marking conditions. The field retroreflectivity measurements are shown in Figure 6.

3.2.1 Retroreflectivity Values in this Report

The retroreflectivity values are highlighted by color on a scale from 0 (green) to 500 (red) (with yellow as a mid-point) millicandelas per square meter per lux (mcd) as shown in Figure 6.

3.2.2 Summary of Findings by Measurement Location and Roadway

A summary of findings by measurement location and roadway follows.

Location	1	1	2	2	3	4	4	5	5	6	6	7	7
Direction Measured	SB	NB	SB	NB	SB	SB	NB	WB	EB	WB	EB	NB	SB
Measurements	YCL	YCL	YCL	YCL	White Skip	WEL	YCL	WEL	YCL	YCL	YCL	YCL	YCL
1	98	83	104	79	74	229	63	318	98	64	115	60	59
2	126	112	176	75	60	176	149	348	114	132	115	60	50
3	82	103	154	90	95	247	190	312	128	187	121	68	56
4	163	132	122	152	102	86	151	359	122	143	124	56	63
5	167	158	163	145	123	223	102	358	114	134	150	50	50
6	132	139	182	180	149	199	150	383	127	169	149	57	54
7	141	138	144	106	135	212	88	386	184	112	120	47	53
8	155	97	211	168	161	199	152	367	165	105	104	65	53
9	155	161	143	143	127	208	92	374	169	131	100	56	50
10	162	126	170	164	142	284	117	378	212	142	101	57	54
11	204	150	196	111	133	271	189	370	114	158	113	69	48
12	157	138	165	97	136	274	91	384	141	123	116	55	39
13	161	144	176	109	115	267	125	414	165	133	105	67	50
14	183	137	149	139	219	256	119	408	114	161	104	64	62
15	132	110	151	111	157	270	88	397	130	166	85	53	50
16	98	96	117	141	183	207	117	347	149	157	86	72	36
Average	136		142		132	226	124	369	140	126		56	
Min	82		75		60	86	63	312	98	64		36	
Max	204		211		219	284	190	414	212	187		72	

Figure 3-2 Eden Prairie Field Retroreflectivity Measurements (mcd)

3.2.3 Measurement Location #1 (Rowland Road, AADT 1,050 in 2012)

2013: New seal coat with yellow centerline painted with latex paint
2014: Restriped using epoxy paint
2015: Field observations for yellow centerline: Daytime presence was good with visible loss in some areas as shown in Figure 7. The retroreflectivity of the yellow centerline was measured in both directions with the average being 136 mcd. The minimum and maximum observations were 82 and 204 mcd respectively.

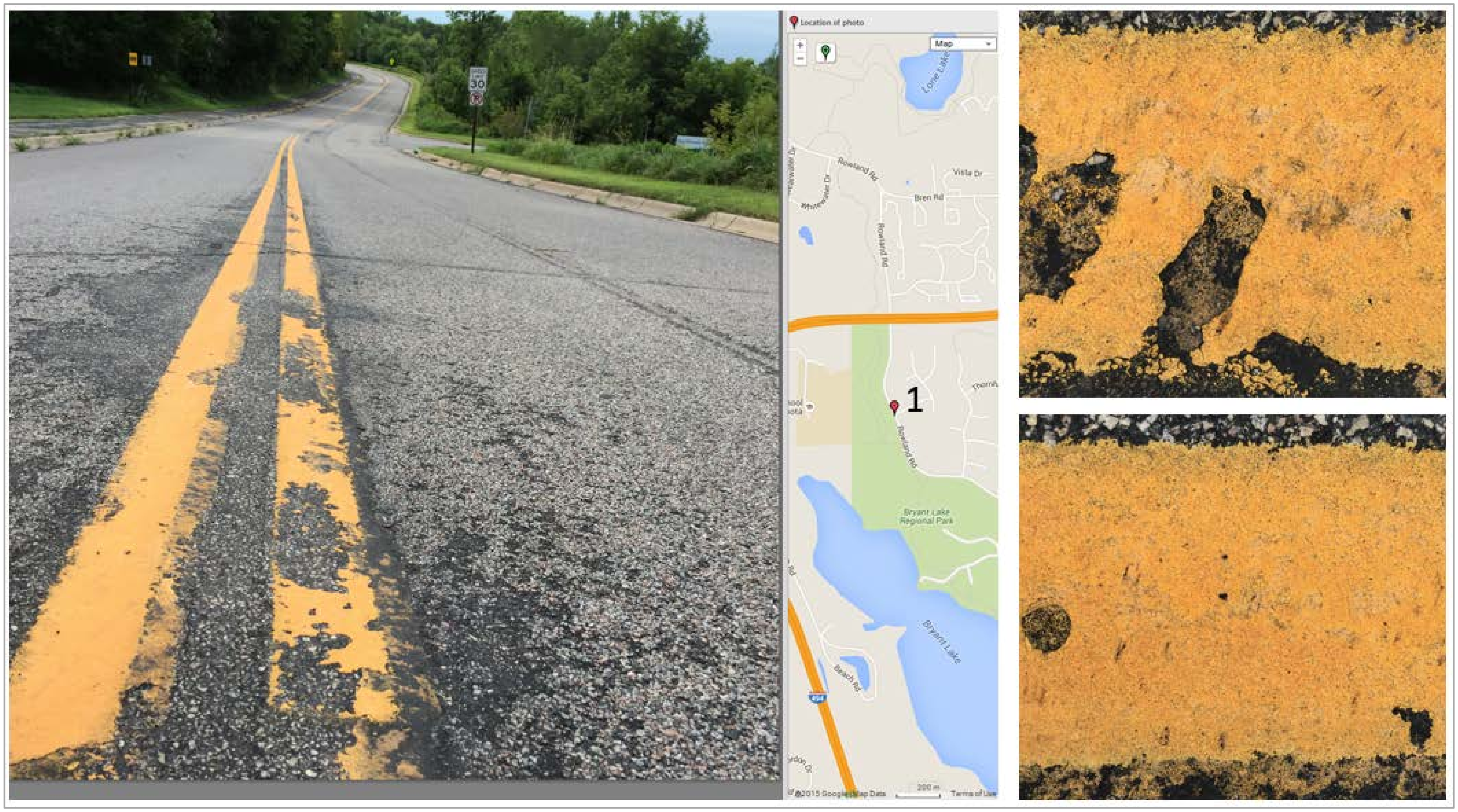


Figure 3-3. Location #1 - Rowland Road (left), Location (center), and Typical Marking Conditions (right)

3.2.4 Measurement Location #2 (Rowland Road, AADT 2,750 in 2012)

2013: New seal coat with yellow centerline painted with latex paint
2014: Restriped using epoxy paint
2015: Field observations for yellow centerline: Daytime presence was good with visible loss in some areas as shown in Figure 8. The retroreflectivity of the yellow centerline was measured in both directions with the average being 142 mcd. The minimum and maximum observations were 75 and 211 mcd respectively.

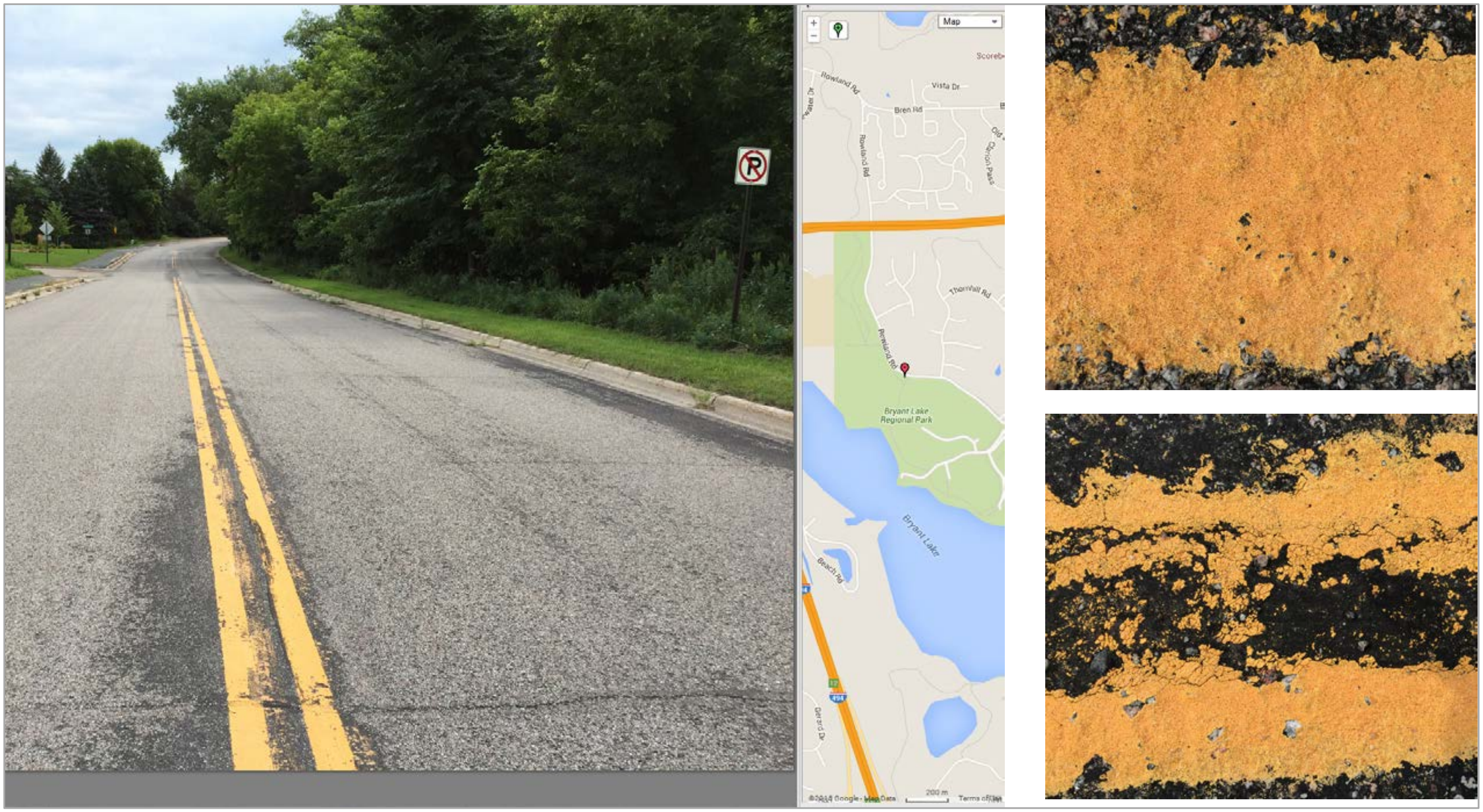


Figure 3-4. Location #2: Rowland Road (left), Location (center), and Typical Marking Conditions (right)

3.2.5 Measurement Location #3 (Mitchell Road, AADT 19,300 in 2012)

2013: New seal coat and white skip line painted with latex paint
2014: Restriped using epoxy paint
2015: Field observations for the southbound white skip line: Daytime presence was good with little visible loss as shown in Figure 9. The retroreflectivity of the white skip line was measured in the southbound travel direction with the average being 132 mcd. The minimum and maximum observations were 60 and 219 mcd respectively.

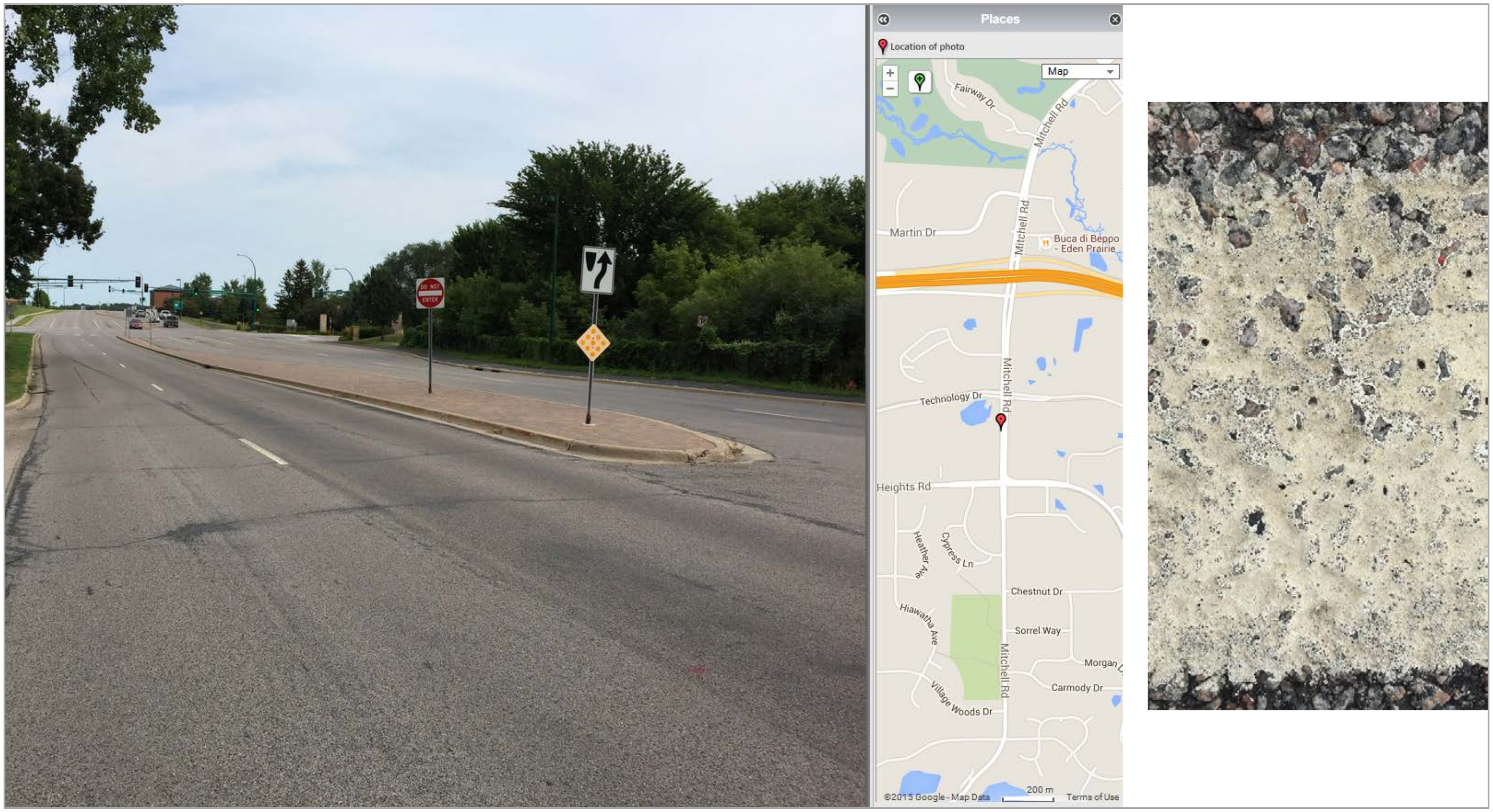


Figure 3-5. Location #3 Mitchell Road (left), Location (center), and Typical Marking Conditions (right)

3.2.6 Measurement Location #4 (Mitchell Road, AADT 4,400 in 2012)

2013: New seal coat and white edge and yellow centerlines painted with latex paint and 2014: Restriped using epoxy paint
2015: Field observations: Daytime presence for both lines was good with some material loss present as shown in Figure 10. The retroreflectivity of the white edgeline was measured in the southbound travel direction with the average being 226 mcd. The minimum and maximum observations were 86 and 284 mcd respectively. The retroreflectivity of the yellow centerline was measured in the northbound travel direction with the average being 124 mcd. The minimum and maximum observations were 63 and 190 mcd respectively.

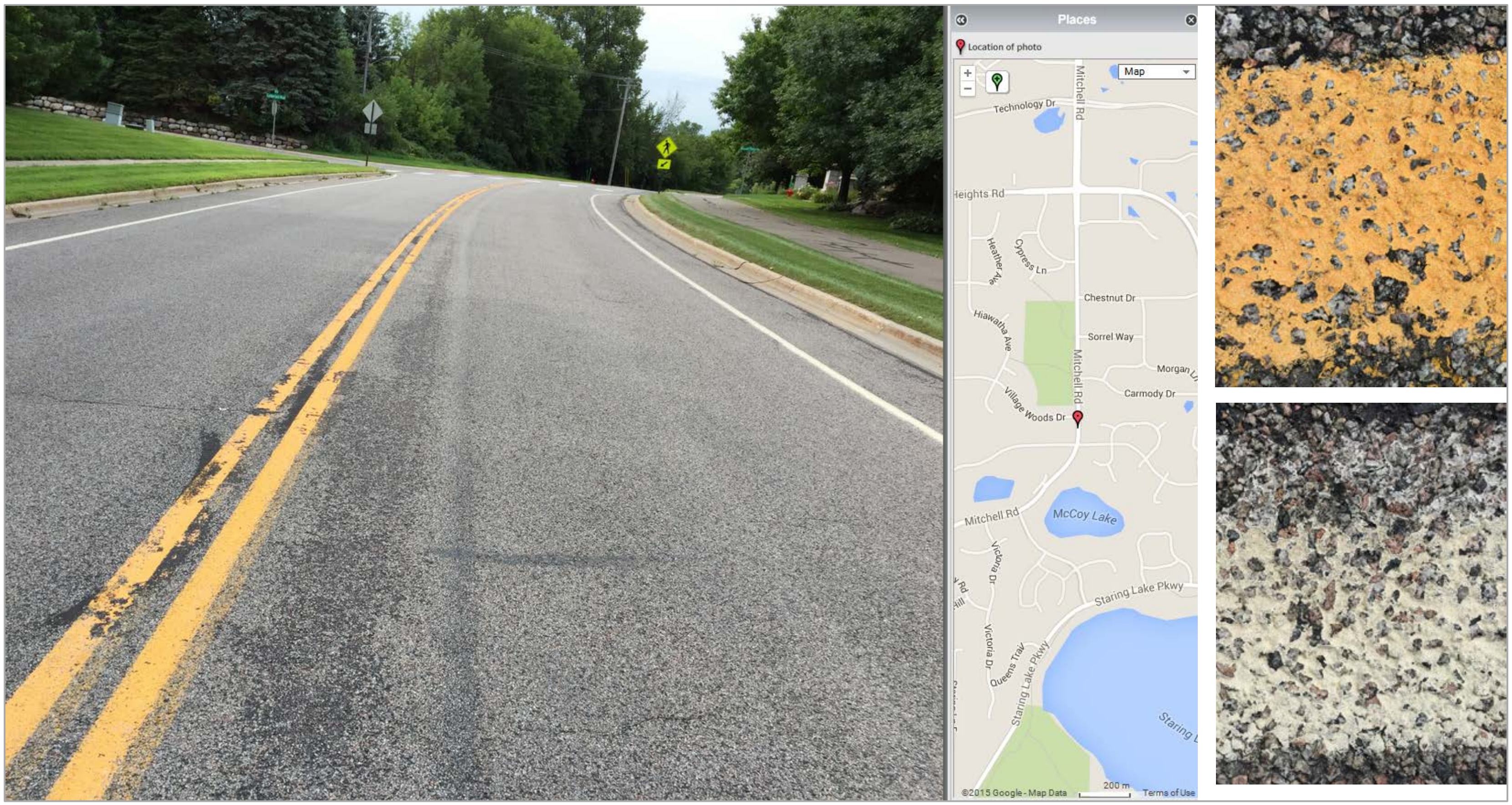


Figure 3-6. Location #4 Mitchell Road (left), Location (center), and Typical Marking Conditions (right)

3.2.7 Measurement Location #5 (Scenic Heights Road, AADT 4,250 in 2012)

2012: New seal coat and white edge and yellow centerlines painted with epoxy paint
2015: Field observations: Daytime presence for both lines was excellent with little material loss present as shown in Figure 11. The retroreflectivity of the white edgeline was measured in the westbound travel direction with the average being 369 mcd. The minimum and maximum observations were 312 and 414 mcd respectively. Retroreflectivity of the yellow centerline was measured in the eastbound travel direction with the average being 140 mcd. The minimum and maximum observations were 98 and 212 mcd respectively. **After measurement, the City confirmed that in-fact this roadway was restriped with epoxy in 2014.**

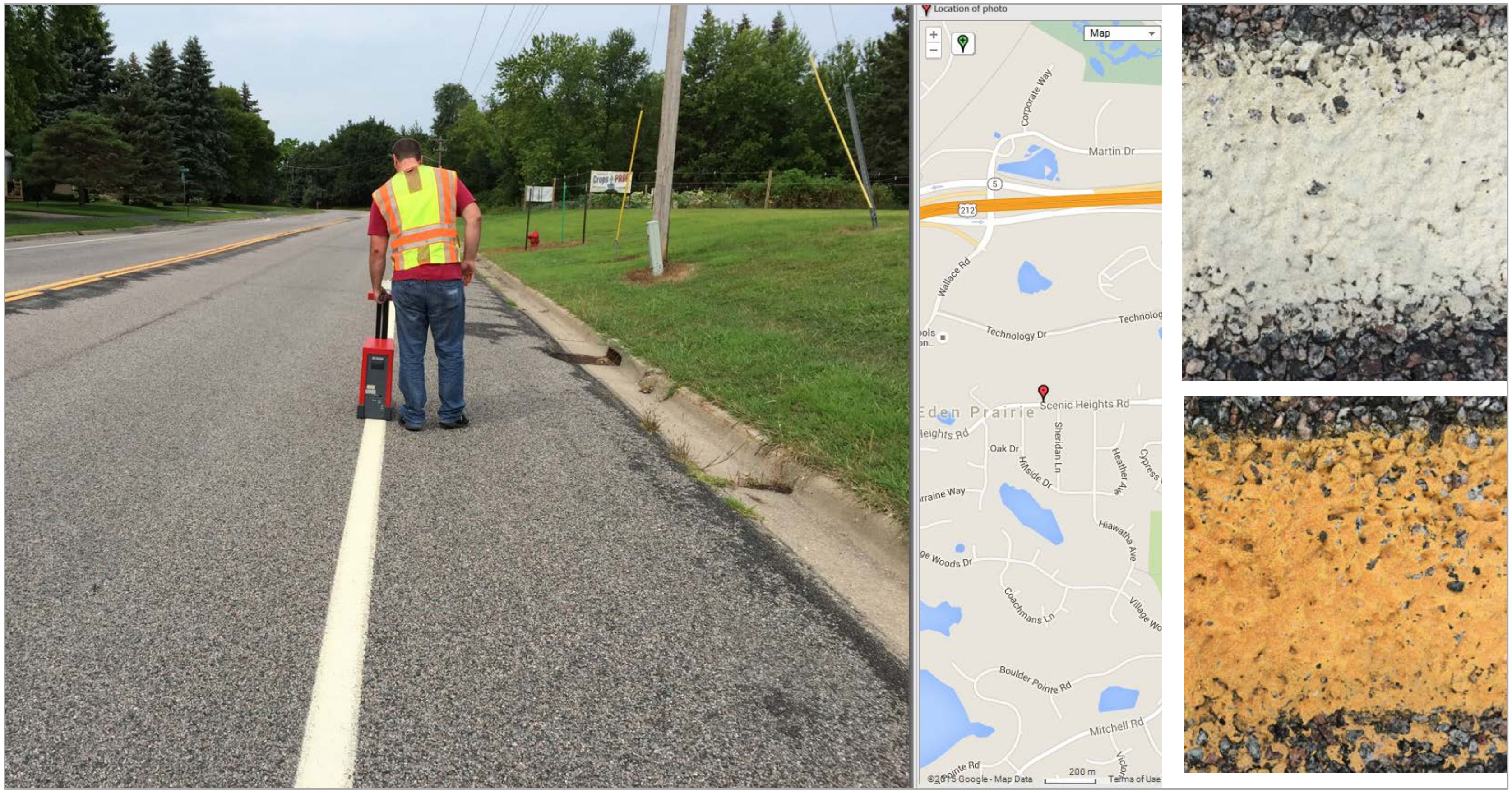


Figure 3-7. Location #5 Scenic Heights Road (left), Location (center), and Typical Marking Conditions (right)

3.2.8 Measurement Location #6 (Scenic Heights Road, AADT 3,450 in 2012)

2012: New seal coat and yellow centerline painted with epoxy paint
2015: Field observations: Daytime presence for both lines was good with some material loss present as shown in Figure 12. The retroreflectivity of the yellow centerline was measured in both travel directions with the average being 126 mcd. The minimum and maximum observations were 64 and 187 mcd respectively.

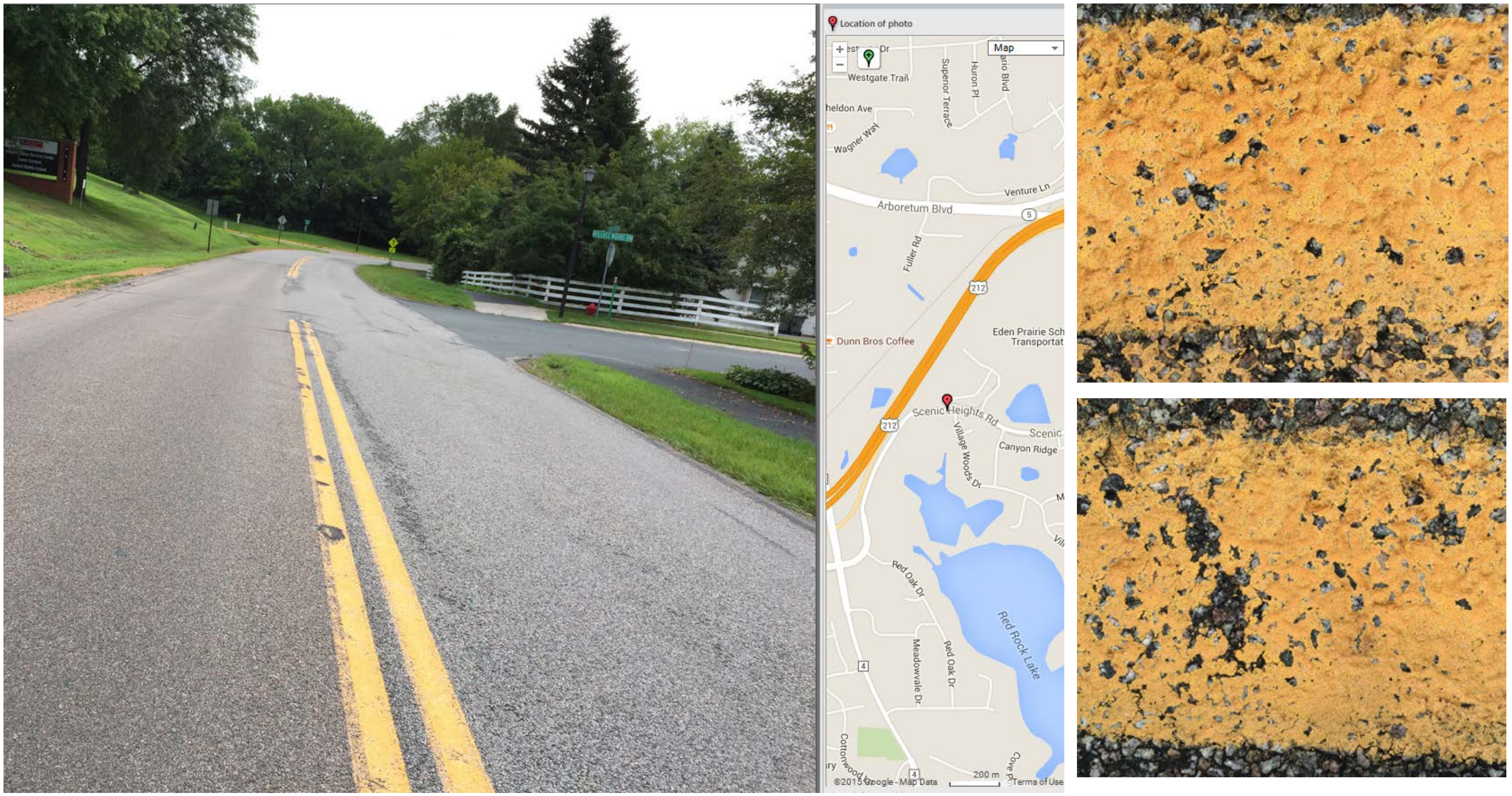


Figure 3-8. Location #6 Scenic Heights Road (left), Location (center), and Typical Marking Conditions (right)

3.2.9 Measurement Location #7 (Riley Lake Road, AADT 1,150 in 2012)

2012: New seal coat and yellow centerline painted with epoxy paint
2015: Field observations: Daytime presence was marginal with considerable material loss present as shown in Figure 13. The retroreflectivity of the yellow centerline was measured in both travel directions with the average being 56 mcd. The minimum and maximum observations were 36 and 72 mcd respectively.

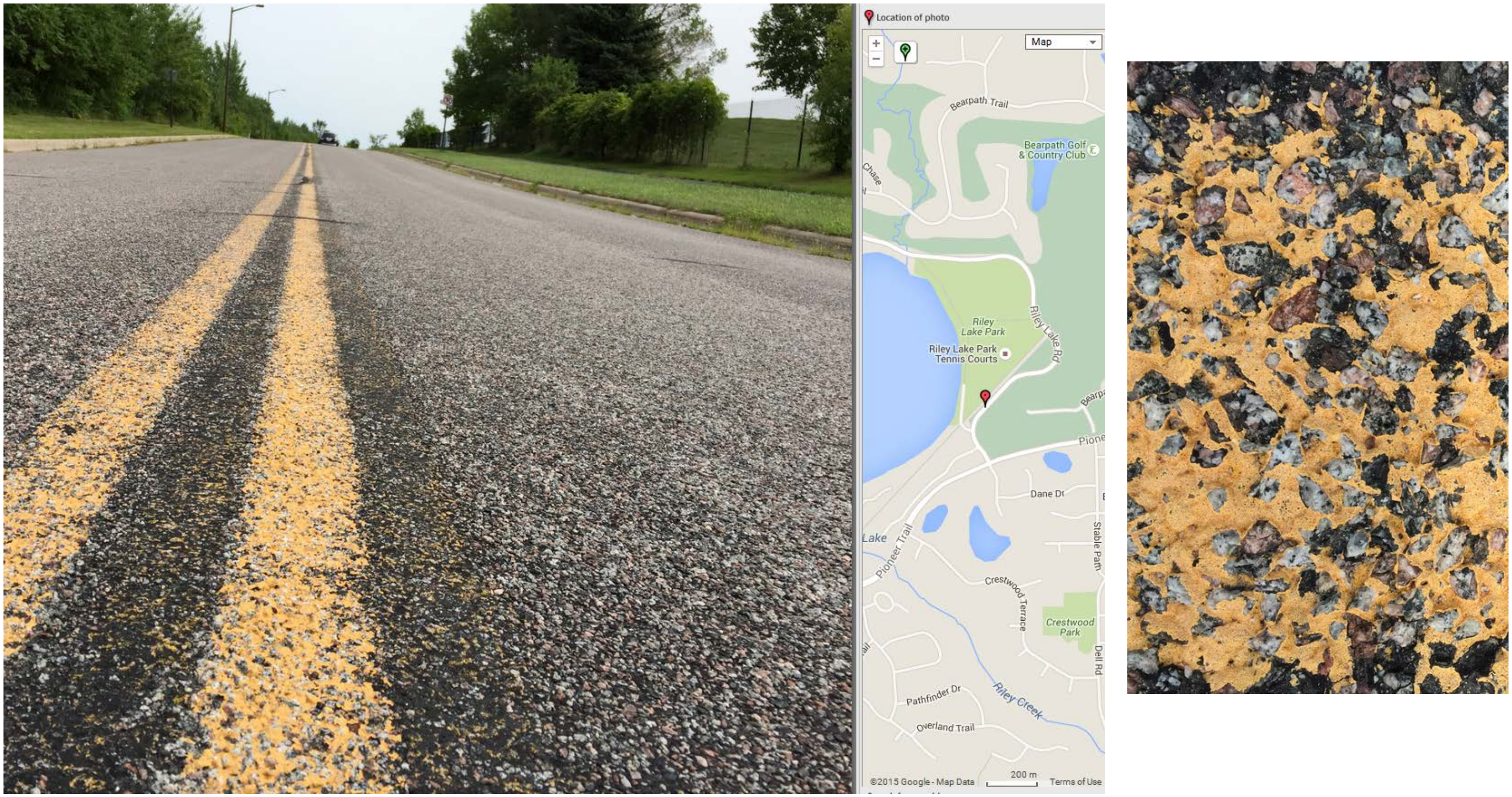


Figure 3-9. Location #7 Riley Lake Road (left), Location (center), and Typical Marking Conditions (right)

Chapter 4. Test Deck Installation

Based on the findings from Task 1A, the research team worked with paint vendors, bead manufacturers, and MnDOT staff to develop a final test deck layout plan, as shown in Figure 15.

From this plan, the research team worked to schedule the installations for the last week of August 2013. The installation included marking out the test sections, applying primer to appropriate sections, and then installing the pavement marking materials (Figure 14).

Figure 4-1. Test Deck Layout and Primer Installation

Participants included the project manager, Neal Hawkins (CTRE at ISU) and the following:

Vendors:	Potters: Bob Hanson and Tom Still (glass beads and VISILOK) Vogel Traffic Paint: Stan Hibma DOW: Cindy Randazzo (paint/resin)
MnDOT:	Michelle Moser, Wayne Lindbloom, Brad Lechtenberg, Paul Nolan, Ken Johnson, Peter Buchen, Nick Prudoehl, Mark Watson, Bruce Daniel, Sheila Johnson, and others.
Trucks included:	Rochester latex truck for high build, Oakdale truck for latex, D1 truck for HPS-4 epoxy, and D6 truck for MFUA-10

US 61 Seal Coat Two-Lane Roadway

Location:	1			2				3				4			5
Section:	A	B	Gap	A	B		Gap	A	B		Gap	A	B	Gap	B
Sub-Section					B-1	B-2			B-1	B-2					
Length (ft):	1,500	1,500	100	1,500	750	750	100	1,500	750	750	100	1,500	1,500	100	1,500
Latex Primer:	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Material:	**Latex**	**Latex**		**High Build**	**High Build**	**High Build**		**High Build**	**High Build**	**High Build**		**HPS4**	**HPS4**		**MFUA-10**
Paint Thickness (mil):	12	12		25	25	25		35	35	35		12	12		12
Reflective Media:	Std MnDOT	Std MnDOT		Visiblend	Visiblend	Visiblend		Visiblend	Visiblend	Visiblend		Std MnDOT	Std MnDOT		Std MnDOT
Drying Agent:						Visiloc		Visilok	Visilok						
4" Yellow Centerline Skip	YCL			YCL				YCL				YCL			YCL
4" White Edge Line	WEL			WEL				WEL				WEL			WEL

US 52 Microsurface Multi-Lane Roadway

Location:	1			2				3				4			5
Section:	A	B	Gap	A	B		Gap	A	B		Gap	A	B	Gap	B
Sub-Section					B-1	B-2			B-1	B-2					
Length (ft):	1,500	1,500	100	1,500	750	750	100	1,500	750	750	100	1,500	1,500	100	1,500
Latex Primer:	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Material:	**Latex**	**Latex**		**High Build**	**High Build**	**High Build**		**High Build**	**High Build**	**High Build**		**HPS4**	**HPS4**		**MFUA-10**
Paint Thickness (mil):	12	12		25	25	25		35	35	35		12	12		12
Reflective Media:	Std MnDOT	Std MnDOT		Visiblend	Visiblend	Visiblend		Visiblend	Visiblend	Visiblend		Std MnDOT	Std MnDOT		Std MnDOT
Drying Agent:						Visilok		Visilok	Visilok						
4" White Centerline Skip	WSL			WSL				WSL				WSL			WSL
4" White Edge Line	WEL			WEL				WEL				WEL			WEL

Figure 4-2. Final Evaluation Plan

4.1 Installation Details

4.1.1 Weather and Roadway Conditions

The weather during the pavement marking installations on August 28, 2013 was sunny, hot and dry with an air temperature between 81° and 88° F. The roadway temperatures, at time of placement, were 110° F on US 61 and 115° F on US 52. The test sections for each roadway had a newly placed surface including US 61 (new seal coat), US 52 (new micro surface). See Figure 16 for additional roadway details. All sections were installed with the exception of the HPS-4, which was delayed due to a mechanical issue on MnDOT application truck.

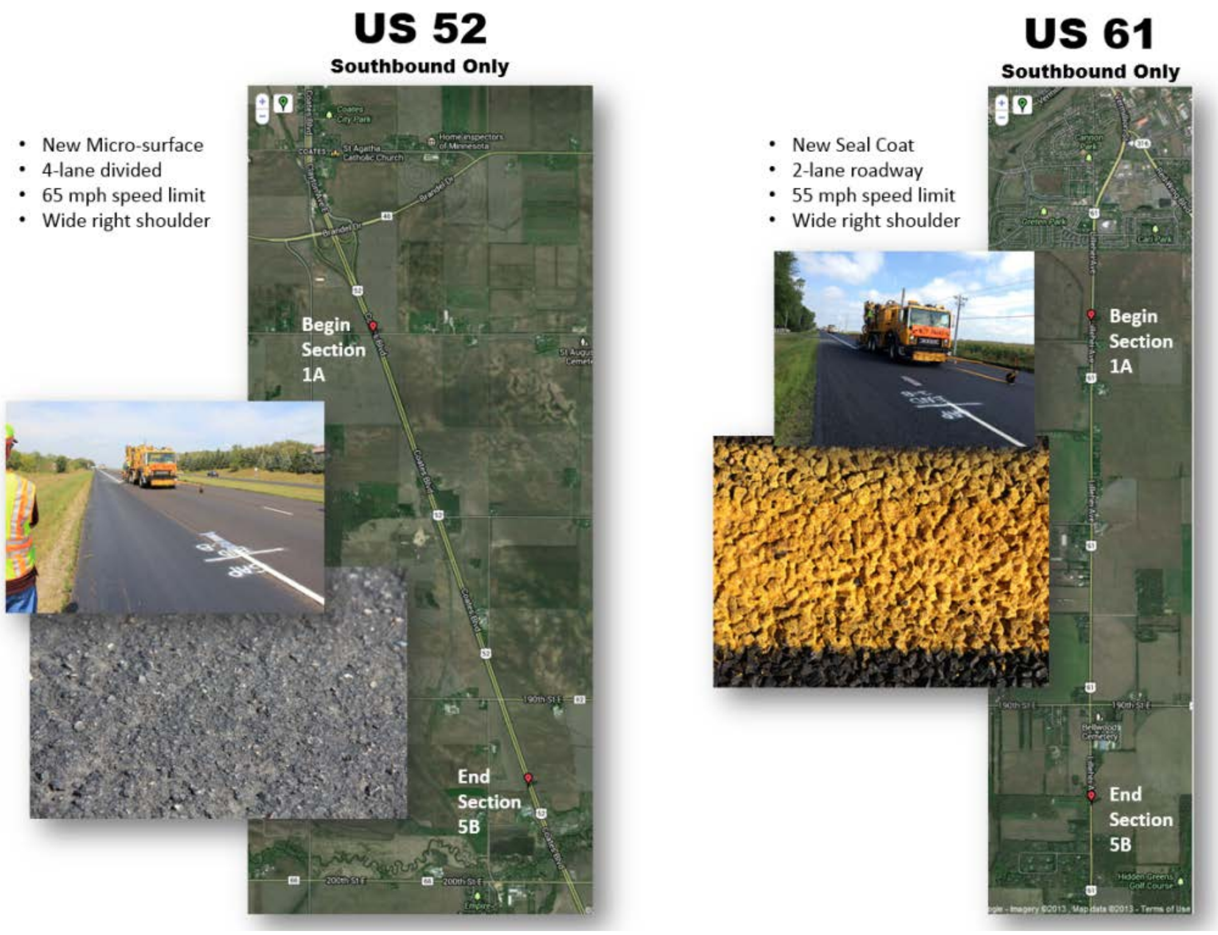


Figure 4-3. Roadway Information for Evaluation Sections

4.1.2 Marking Materials by Test Section

1. Latex – Standard MnDOT latex material (12 mil wet thickness) for control, also used as primer. MnDOT provider was Vogel Traffic Services: white was UC1515 and yellow was UC3590. Reflective media included standard MnDOT M-247.

2. High Build - High build waterborne (FASTRACK HD21A) (25 mil wet thickness). MnDOT provider was Vogel Traffic Services: white was VLX15562 and yellow was VLX15563. Reflective media included Visiblend supplied by Potters.

3. High Build - High build waterborne (FASTRACK HD21A) (35 mil wet thickness). MnDOT provider was Vogel Traffic Services. Included VISILOK drying agent. Reflective media included Visiblend supplied by Potters.

4. HPS-4 – Standard MnDOT epoxy material (12 mil wet thickness). Reflective media included standard MnDOT M-247.

5. MFUA-10 – Standard MnDOT-modified urethane material (12 mil wet thickness). Reflective media included standard MnDOT M-247.

4.1.3 Reflective Media Application Rates

- M247 glass bead were applied at 8 pounds per gallon.
- VISILOK drying agent was applied at 2 pounds per gallon on both the 25 and 35 mil paint applications.
- Visiblend was applied at 10 pounds per gallon. Visiblend consisted of Type 1 and 3 beads with 15 percent Ultra 1.9 beads blended.

4.1.4 No Track Times

The VISILOK drying agent speeds up no-track dry times and allows agencies to use thicker, and presumably more durable, marking materials. Figure 17 shows the no-track times recorded (by Bob Hanson of Potters) for the test decks with and without the VISILOK product. As shown, the average no-track time was reduced by 57 percent.

				No Track Time in Minutes		
Roadway	Surface	Wet Mil Thickness	Line Type	Without Visilok	With Visilok	% Difference
US 61	Seal Coat	25	White Edge Line	1.9	0.9	-52%
US 61	Seal Coat	25	Yellow Centerline Skip	2.5	0.8	-67%
US 61	Seal Coat	35	White Edge Line	2.1	1.3	-40%
US 61	Seal Coat	35	Yellow Centerline Skip	4.0	1.8	-56%
US 52	Micro Surface	25	White Edge Line	1.3	0.6	-56%
US 52	Micro Surface	25	White Skip Line	1.3	0.5	-63%
US 52	Micro Surface	35	White Edge Line	3.3	1.3	-63%
US 52	Micro Surface	35	White Skip Line	1.3	0.5	-63%
			Average=	2.2	0.9	-57%

Figure 4-4. Recorded No-Track Times

4.1.5 Installation

The installation for each section was completed without any equipment issues. Technical representatives for both the paint and bead products were either riding with the paint truck or along the roadside to make minor adjustments to ensure compliance with the desired evaluation plan. Figure 18 provides several images from the installations.

Figure 4-5. Installation

Sample plates were obtained during the installation of the high build and MFUA products. The test plates serve as a record of the installation conditions for paint and bead application and are a source for images (see Figure 19).

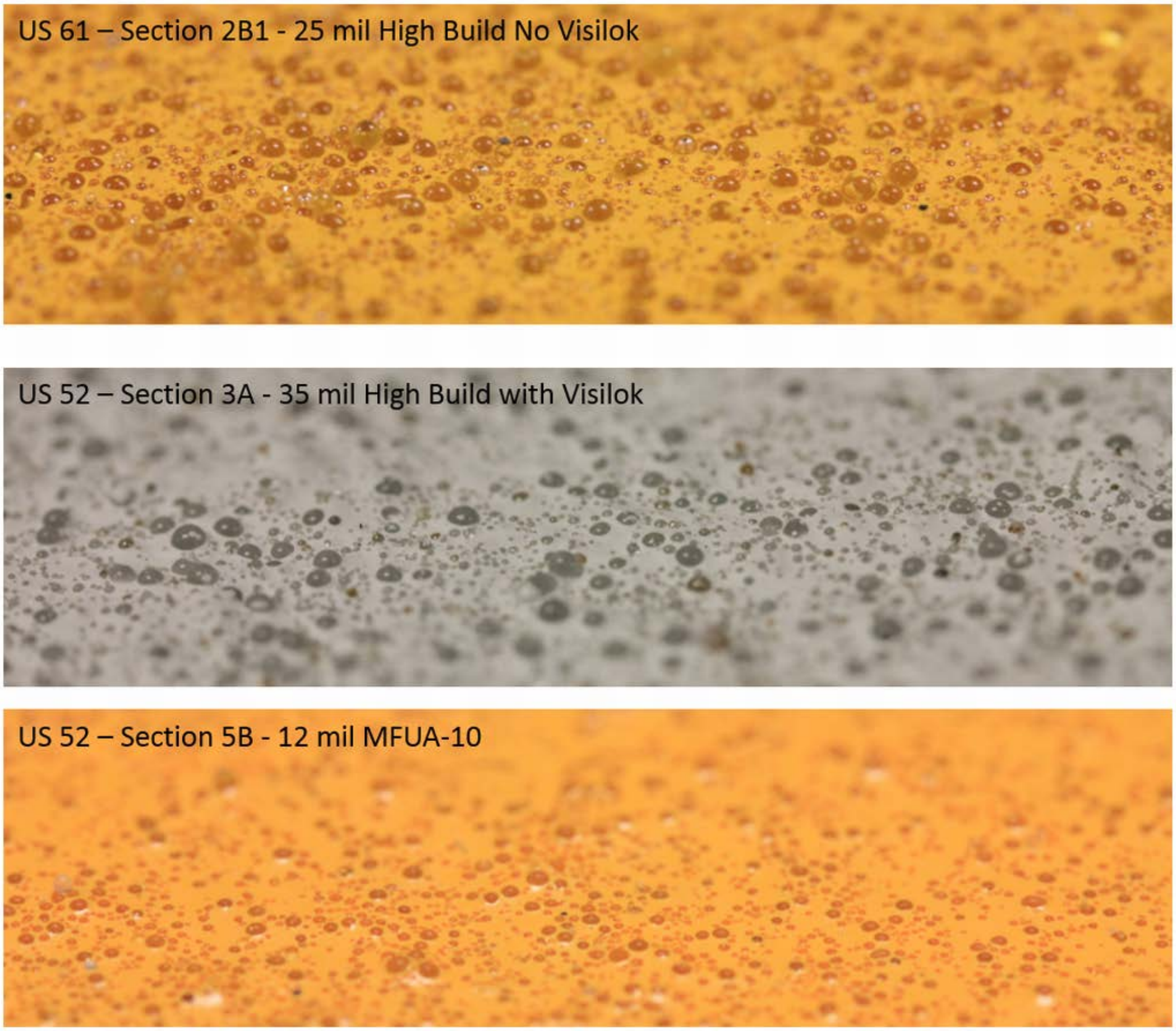


Figure 4-6. Sample Plate Images

Chapter 5. Measuring and Monitoring

5.1 Schedule

This task provides quantification of the pavement marking performance over time. Given that this will occur over several years, Task 3 was subdivided as follows:

- Task 3A – Initial measurement after installation and before winter (2013)
- Task 3B – Measurement after the first winter (2014)
- Task 3C – Measurement after the second winter (2015)

5.2 Measurement Equipment

Retroreflectivity readings were measured using a hand-held retroreflectometer (LTL-X) (see Figure 20).

Figure 5-1. Handheld Retroreflectometer

The standard test procedure defined by ASTM 1710-11 was followed in determining the coefficient of retroreflected luminance of horizontal coating materials used in the test pavement markings.

5.3 Sampling Protocol

Based on MnDOT skip-line spacing, 16 measurements were taken over 400 feet within each test segment. The process included the following:

1. Calibrate the handheld instrument according to the manufacturer recommendations.
2. Pre-load the section labels by roadway in the LTL.
3. Locate each field sampling section using the roadway markings in-place. Select areas that are typical of the marking section.
4. Take all measurements in the direction of travel.
5. Center the device on the pavement marking and for each edgeline, take 16 equally spaced readings within the 400-foot sampling area regardless of the condition of the line. On each lane line, take 2 readings on each skip for 8 consecutive skips.
6. Data entry for handheld instrument:

a. Select the test section from the pre-loaded list.
b. Take retroreflective readings using the defined procedure.

5.4 Initial 2013 Measurements

Figure 21 summarizes the initial retroreflectivity readings measured in the fall of 2013.

Roadway	Line Type	Measured	1A	1B	2A	2B1	2B2	3A	3B1	3B2	4A	4B	5B	Average
US 52	White Edge Line	2013	259	263	225	229	243	434	335	256	311	361	353	297
US 52	White Ctrline Skip	2013	276	225	319	199	283	399	331	200	395	387	321	303

Roadway	Line Type	Measured	2A	2B1	2A	2B1	2B2	3A	3B1	3B2	4A	4B	5B	Average
US 61	White Edge Line	2013	226	168	226	269	245	367	286	255	369	342	293	277
US 61	Yellow Center Line	2013	142	112	122	132	123	150	137	121	240	233	134	150

Figure 5-2. Initial Average Retroreflectivity Readings

The retroreflectivity values are highlighted by color on a scale from 0 (green) to 500 (red). As shown, the readings cover a range of retroreflectivity values from a high of 434 millicandelas per square meter per lux (mcd) to a low of 112 mcd.

Figure 22 provides a statistical summary for each roadway, section, and sub-section, including the average, minimum, maximun, standard deviation, and number of readings. Figure 23 provides a visual chart for the initial findings.

These readings would be repeated after one and two winters (2014/2015) or as deemed necessary by the project TAP.

				Retroreflectivity Readings (mcd)				
Roadway	Section	Subsection	Line Type	Average	Min	Max	StdDev	Count
US 52	1	A	WEL	259	159	324	51	20
US 52	1	A	WSL	276	249	321	19	22
US 52	1	B	WEL	263	223	307	24	20
US 52	1	B	WSL	225	189	265	22	16
US 52	2	A	WEL	225	162	352	54	20
US 52	2	A	WSL	319	261	387	30	19
US 52	2	B1	WEL	229	176	324	41	16
US 52	2	B1	WSL	199	159	266	26	16
US 52	2	B2	WEL	243	166	333	52	16
US 52	2	B2	WSL	283	212	334	41	16
US 52	3	A	WEL	434	386	484	27	20
US 52	3	A	WSL	399	311	493	51	16
US 52	3	B1	WEL	335	289	390	31	16
US 52	3	B1	WSL	331	201	456	65	16
US 52	3	B2	WEL	256	207	296	31	16
US 52	3	B2	WSL	200	140	334	64	16
US 52	4	A	WEL	311	262	342	27	20
US 52	4	A	WSL	395	358	426	18	16
US 52	4	B	WEL	361	327	384	18	20
US 52	4	B	WSL	387	374	397	6	16
US 52	5	B	WEL	353	335	384	17	20
US 52	5	B	WSL	321	302	336	9	16
US 61	1	A	WEL	226	197	252	15	20
US 61	1	A	YCL	142	126	158	8	16
US 61	1	B	WEL	168	126	200	19	20
US 61	1	B	YCL	112	92	136	12	18
US 61	2	A	WEL	226	159	312	53	20
US 61	2	A	YCL	122	99	157	16	16
US 61	2	B1	WEL	269	183	350	42	16
US 61	2	B1	YCL	132	84	168	20	14
US 61	2	B2	WEL	245	204	297	26	19
US 61	2	B2	YCL	123	84	171	27	16
US 61	3	A	WEL	367	288	422	33	20
US 61	3	A	YCL	150	110	179	18	15
US 61	3	B1	WEL	286	226	337	37	16
US 61	3	B1	YCL	137	111	177	23	16
US 61	3	B2	WEL	255	215	278	17	16
US 61	3	B2	YCL	121	95	149	15	16
US 61	4	A	WEL	369	338	393	17	20
US 61	4	A	YCL	240	219	261	10	16
US 61	4	B	WEL	342	282	392	27	20
US 61	4	B	YCL	233	205	258	16	16
US 61	5	B	WEL	293	248	336	23	20
US 61	5	B	YCL	134	107	171	16	16

Figure 5-3. Initial Measurement Statistics

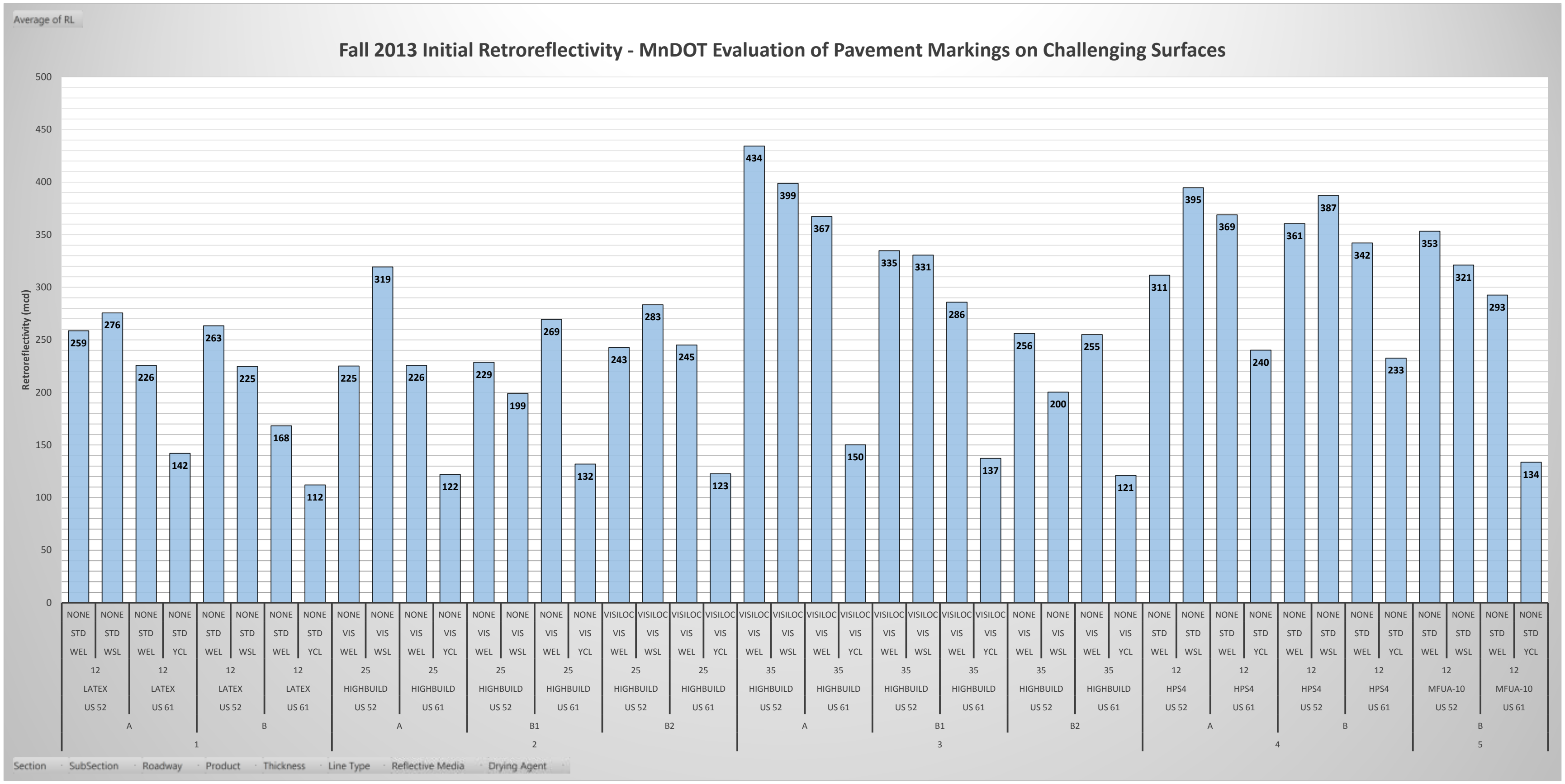


Figure 5-4. Initial Retroreflectivity by Section

Selected images from the 2013 measurements are shown in Figure 24.

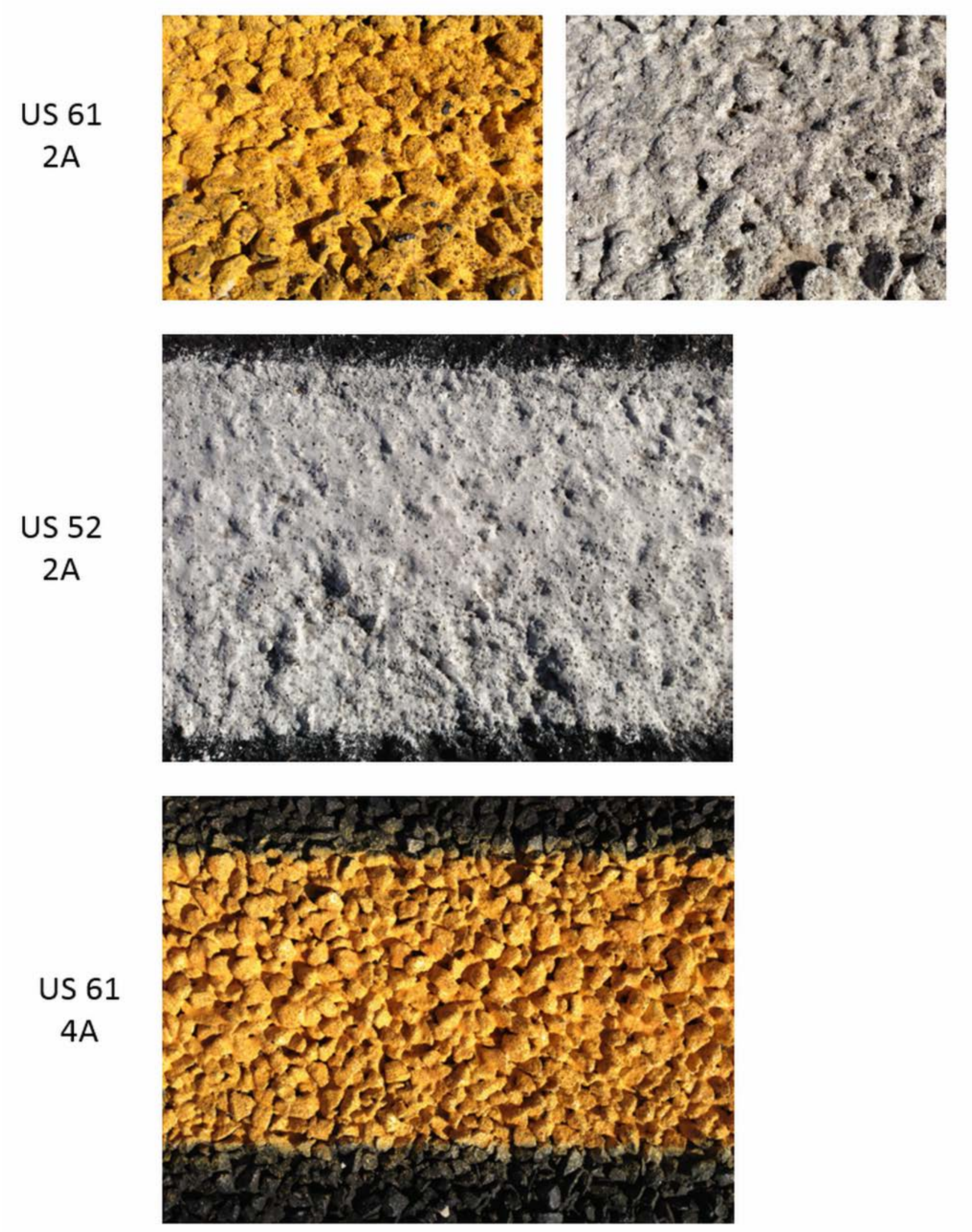


Figure 5-5. Initial Pavement Marking Conditions

5.5 2014 Measurements after One Winter

5.5.1 Eliminated Test Segments

Prior to the 2014 measurements (after 1 winter), MnDOT advised the research team that the following test segments would be eliminated from further measuring and monitoring efforts:

- US 61 - The seal coat surface installed was determined to have failed due to paving material issues that were unrelated to the pavement marking evaluation. This resulted in the entire US 61 test deck being eliminated from this evaluation.

- US 52 - Two sections on US 52: Latex on sections 1A and 1B, required restriping prior to the 2014 field measurements. This resulted in Sections 1A and 1B of the US 52 test deck being eliminated from the study.

5.5.2 2014 Measurements

Figure 25 shows the retroreflectivity measurements on US 52 by section for both 2013 (initial) and 2014 (after one winter) readings in addition to the calculated percent difference and averages between the two readings. Figure 25 combines the 2013 and 2014 findings, the material, and installation details for each test section.

Roadway	Line Type	Measured	2A	2B1	2B2	3A	3B1	3B2	4A	4B	5B	Average
US 52	White Edge Line	2013	225	229	243	434	335	256	311	361	353	305
US 52	White Edge Line	2014	106	112	97	220	150	151	209	204	199	161
		Difference (%)	-53%	-51%	-60%	-49%	-55%	-41%	-33%	-43%	-44%	

Roadway	Line Type	Measured	2A	2B1	2B2	3A	3B1	3B2	4A	4B	5B	Average
US 52	White Ctrline Skip	2013	319	199	283	399	331	200	395	387	321	315
US 52	White Ctrline Skip	2014	114	82	136	137	140	140	226	164	166	145
		Difference (%)	-64%	-59%	-52%	-66%	-58%	-30%	-43%	-58%	-48%	

Figure 5-6. US 52 Performance for 2013 and 2014

5.5.3 Observations after One Winter

5.5.3.1 White Edgelines

Figure 25 shows that, after one winter, the white edgeline average retroreflectivity readings ranged from 97 mcd (Section 2B2, 25 mil High Build) to 209 mcd (Section 4A, 12 mil HPS4), of which these same two sections had the highest and lowest percent change in value at -60% (Section 2B2, 25 mil High Build) and -33% (Section 4A, 12 mil HPS4). The product with the highest initial retroreflectivity (Section 3A, 35 mil High Build) remained the highest after one winter at 220 mcd. The other sections of High Build (Sections 2A, 2B1, 2B2, 3B1, and 3B2) had retroreflectivity readings ranging from 97 mcd to 151 mcd. In contrast, the epoxy (Sections 4A and 4B) and MFUA-10 (Section 5) had retroreflectivity readings at or near 200 mcd after one winter.

5.5.3.2 White Centerline Skip Lines

Figure 25 also shows that, after one winter, the white centerline skip average retroreflectivity readings ranged from 82 mcd (Section 2B1, 25 mil High Build) to 226 mcd (Section 4A, 12 mil HPS4). The percent change in retroreflectivity ranged from -30% (Section 3B2, 35 mil High Build) to -66% (Section 3A, 35 mil High Build). The product with the highest retroreflectivity after one winter (Section 4A, 12 mil HPS4) did not have the highest initial retroreflectivity, but was only 4 mcd away from the highest initial value. The 25 mil High Build sections had the lowest group average after one winter at 110 mcd. The 35 mil High Build sections had an average resulting retroreflectivity of 139 mcd. The Epoxy and MFUA-10 sections had higher resulting readings than any of the High Build sections averaging together at 185 mcd.

Figure 26 shows the results for all sections. Figure 27 and Figure 28 graphically illustrate the change in retroreflectivity for all relevant sections along with the percentage loss experienced.

US 61 Seal Coat Two-Lane Roadway															
Location:	1			2				3				4			5
Section:	A	B	Gap	A	B		Gap	A	B		Gap	A	B	Gap	B
Sub-Section					B-1	B-2			B-1	B-2					
Length (ft):	1,500	1,500	100	1,500	750	750	100	1,500	750	750	100	1,500	1,500	100	1,500
Latex Primer:	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Material:	**Latex**	**Latex**		**High Build**	**High Build**	**High Build**		**High Build**	**High Build**	**High Build**		**HPS4**	**HPS4**		**MFUA-10**
Paint Thickness (mil):	12	12		25	25	25		35	35	35		12	12		12
Reflective Media:	Std MnDOT	Std MnDOT		Visiblend	Visiblend	Visiblend		Visiblend	Visiblend	Visiblend		Std MnDOT	Std MnDOT		Std MnDOT
Drying Agent:						Visilok		Visilok	Visilok						
2013 Retro 4" White Edge Line	226	168		226	269	245		367	286	255		369	342		293
2013 Retro 4" Yellow Ctrline Skip	142	112		122	132	123		150	137	121		240	233		134

US 52 Microsurface Multi-Lane Roadway															
Location:	1			2				3				4			5
Section:	A	B	Gap	A	B		Gap	A	B		Gap	A	B	Gap	B
Sub-Section					B-1	B-2			B-1	B-2					
Length (ft):	1,500	1,500	100	1,500	750	750	100	1,500	750	750	100	1,500	1,500	100	1,500
Latex Primer:	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Material:	**Latex**	**Latex**		**High Build**	**High Build**	**High Build**		**High Build**	**High Build**	**High Build**		**HPS4**	**HPS4**		**MFUA-10**
Paint Thickness (mil):	12	12		25	25	25		35	35	35		12	12		12
Reflective Media:	Std MnDOT	Std MnDOT		Visiblend	Visiblend	Visiblend		Visiblend	Visiblend	Visiblend		Std MnDOT	Std MnDOT		Std MnDOT
Drying Agent:						Visilok		Visilok	Visilok						
2013 Retro 4" White Edge Line	259	263		225	229	243		434	335	256		311	361		353
2014 Retro 4" White Edge Line	NA	NA		106	112	97		220	150	151		209	204		199
2013 Retro 4" White Ctrline Skip	276	225		319	199	283		399	331	200		395	387		321
2014 Retro 4" White Ctrline Skip	NA	NA		114	82	136		137	140	140		226	164		166

Figure 5-7. Performance Over Time by Roadway, Material, and Test Section

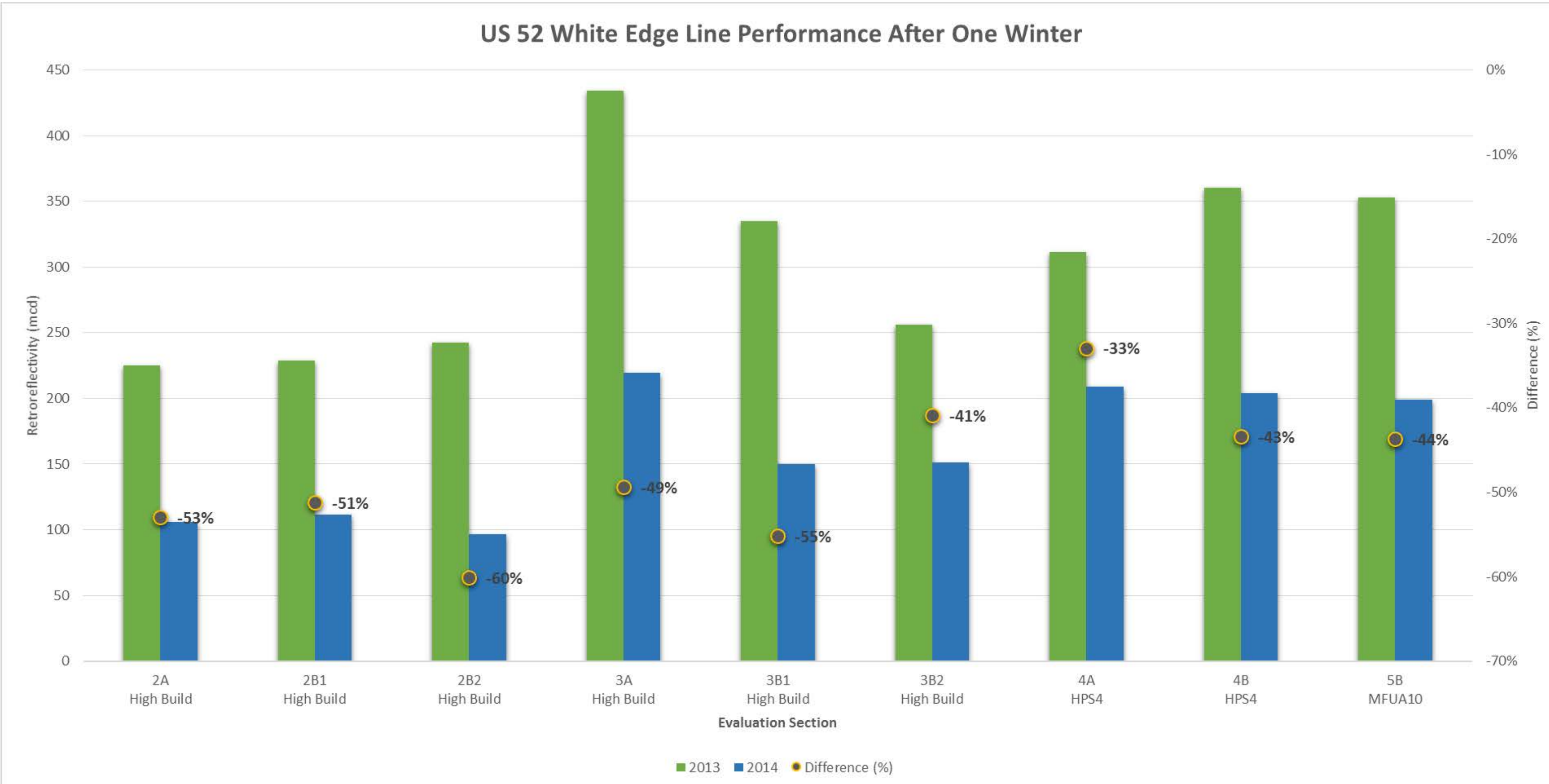


Figure 5-8. US 52 White Edgeline Performance after One Winter by Test Section

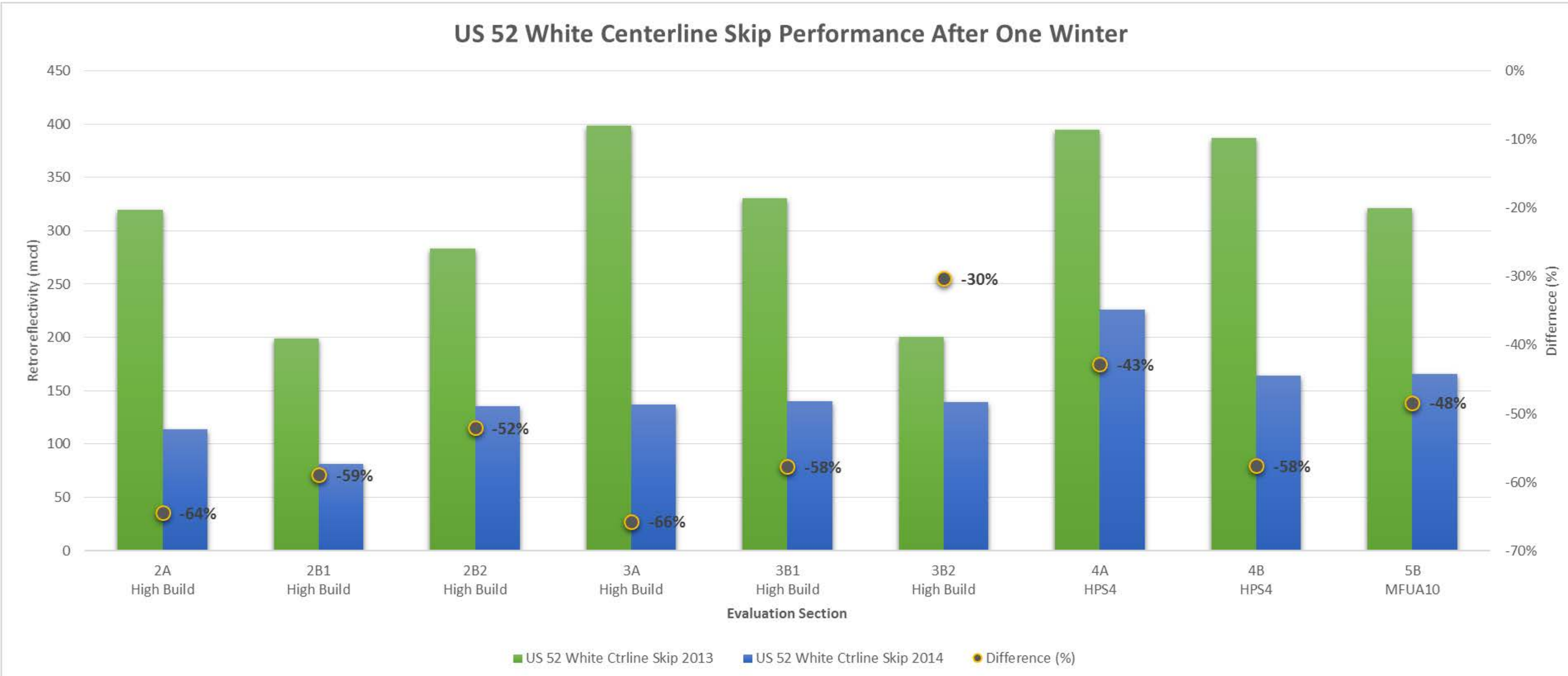


Figure 5-9. US 52 White Centerline Skip Performance after One Winter by Test Section

5.6 2015 Measurements after Two Winters

5.6.1 Eliminated Test Segments

See eliminated test segments earlier in this Chapter under 2014 Measurements after One Winter.

5.6.2 2015 Measurements

Retroreflectivity measurements were made on US 52 by section during 2013 (initial), in 2014 (after one winter), and in May 2015 (after two winters).

5.6.3 Observations after Two Winters

5.6.3.1 White Edgelines

Figure 29 provides the averages of all retroreflectivity readings by year and evaluation section.

Year Measured	2A High Build	2B1 High Build	2B2 High Build	3A High Build	3B1 High Build	3B2 High Build	4A HPS4	4B HPS4	5B MFUA10	Average
2013	225	229	243	434	335	256	311	361	353	305
2014	106	112	97	220	150	151	209	204	199	161
2015	101	114	64	167	101	106	170	177	186	132
% Change	-55%	-50%	-74%	-62%	-70%	-59%	-45%	-51%	-47%	

Figure 5-10. US 52 White Edgeline Retroreflectivity Readings (mcd) by Year and Evaluation Section

The green data bars provide a visual scale for each retroreflectivity average based on a scale from 0 to 500 mcd. The shading for percent change is based on a scale from 0 (green) to -100% (red), of which most of the data fall within the color yellow.

The white edgeline average retroreflectivity readings after two winters (2015 readings) ranged from 64 mcd (Section 2B2, 25 mil High Build) to 186 mcd (Section 5B, 12 mil MFUA-10). The amount of loss, or percent change in retroreflectivity (2013 to 2015), ranged from -45% (Section 4A, HPS4) to -74% (Section 2B2, 25 mil High Build).

The section with the highest initial retroreflectivity value of 434 mcd (Section 3A, 35 mil High Build) did not, after two winters, have the highest resulting value. However, it was within 20 mcd of the highest. Section 5B had the highest retroreflectivity after two winters at 186 mcd, followed closely by the two epoxy sections, 4B and then 4A, at 177 mcd and 170 mcd, respectively.

In contrast to the 167 mcd retroreflectivity for High Build Section 3A, the other High Build sections (Sections 2A, 2B1, 2B2, 3B1, and 3B2) had lower retroreflectivity readings, ranging from 64 mcd to 114 mcd. The epoxy sections (Sections 4A and 4B) and MFUA-10 (Section 5) had retroreflectivity readings at or above 170 mcd after the two winters.

5.6.3.2 White Centerline Skip Lines

Figure 30 provides the averages of all retroreflectivity readings by year and evaluation section for the white centerline skips.

Year Measured	2A High Build	2B1 High Build	2B2 High Build	3A High Build	3B1 High Build	3B2 High Build	4A HPS4	4B HPS4	5B MFUA10	Average
2013	319	199	283	399	331	200	395	387	321	315
2014	114	82	136	137	140	140	226	164	166	145
2015	94	67	102	104	105	114	201	163	127	120
% Change	-71%	-66%	-64%	-74%	-68%	-43%	-49%	-58%	-60%	

Figure 5-11. US 52 White Edgeline Retroreflectivity Readings (mcd) by Year and Evaluation Section

The green data bars provide a visual scale for each retroreflectivity average based on a scale from 0 to 500 mcd. The shading for percent change is based on a scale from 0 (green) to -100% (red) of which most of the data fall within the color yellow.

The white centerline skip average retroreflectivity readings after two winters (2015 readings) ranged from 67 mcd (Section 2B1, 25 mil High Build) to 201 mcd (Section 4A, 12 mil HPS4). The amount of loss, or percent change in retroreflectivity (2013 to 2015), ranged from -43% (Section 3B2, 35 mil High Build) to -74% (Section 3A, 35 mil High Build).

The section with the highest initial retroreflectivity value of 399 mcd (Section 3A, 35 mil High Build) did not, after two winters, have the highest resulting value. Section 4A had the highest retroreflectivity after two winters at 201 mcd followed by Section 4B2 at 163 mcd.

The High Build sections (Sections 2A, 2B1, 2B2, 3A, 3B1, and 3B2) had the lowest retroreflectivity readings after two winters ranging from 67 mcd to 114 mcd. Sections 4A and 4B had the highest results at 201 mcd and 163 mcd respectively followed by the MFUA-10 (Section 5B) at 127 mcd.

Figure 31 shows the retroreflectivity results to date for all sections. Figure 32 and Figure 33 graphically illustrate the change in retroreflectivity for all relevant sections along with the percentage loss experienced.

US 61 Seal Coat Two-Lane Roadway

Location:	1			2				3				4			5
Section:	A	B	Gap	A	B		Gap	A	B		Gap	A	B	Gap	B
Sub-Section					B-1	B-2			B-1	B-2					
Length (ft):	1,500	1,500	100	1,500	750	750	100	1,500	750	750	100	1,500	1,500	100	1,500
Latex Primer:	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Material:	**Latex**	**Latex**		**High Build**	**High Build**	**High Build**		**High Build**	**High Build**	**High Build**		**HPS4**	**HPS4**		**MFUA-10**
Paint Thickness (mil):	12	12		25	25	25		35	35	35		12	12		12
Reflective Media:	Std MnDOT	Std MnDOT		Visiblend	Visiblend	Visiblend		Visiblend	Visiblend	Visiblend		Std MnDOT	Std MnDOT		Std MnDOT
Drying Agent:						Visilok		Visilok	Visilok						
2013 Retro 4" White Edge Line	226	168		226	269	245		367	286	255		369	342		293
2013 Retro 4" Yellow Ctrline Skip	142	112		122	132	123		150	137	121		240	233		134

US 52 Microsurface Multi-Lane Roadway

Location:	1			2				3				4			5
Section:	A	B	Gap	A	B		Gap	A	B		Gap	A	B	Gap	B
Sub-Section					B-1	B-2			B-1	B-2					
Length (ft):	1,500	1,500	100	1,500	750	750	100	1,500	750	750	100	1,500	1,500	100	1,500
Latex Primer:	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Material:	**Latex**	**Latex**		**High Build**	**High Build**	**High Build**		**High Build**	**High Build**	**High Build**		**HPS4**	**HPS4**		**MFUA-10**
Paint Thickness (mil):	12	12		25	25	25		35	35	35		12	12		12
Reflective Media:	Std MnDOT	Std MnDOT		Visiblend	Visiblend	Visiblend		Visiblend	Visiblend	Visiblend		Std MnDOT	Std MnDOT		Std MnDOT
Drying Agent:						Visilok		Visilok	Visilok						
2013 Retro 4" White Edge Line	259	263		225	229	243		434	335	256		311	361		353
2014 Retro 4" White Edge Line	NA	NA		106	112	97		220	150	151		209	204		199
2015 Retro 4" White Edge Line	NA	NA		101	114	64		167	101	106		170	177		186
2013 Retro 4" White Ctrline Skip	276	225		319	199	283		399	331	200		395	387		321
2014 Retro 4" White Ctrline Skip	NA	NA		114	82	136		137	140	140		226	164		166
2015 Retro 4" White Ctrline Skip	NA	NA		94	67	102		104	105	114		201	163		127

Figure 5-12. Performance over Time by Roadway, Material, and Test Section

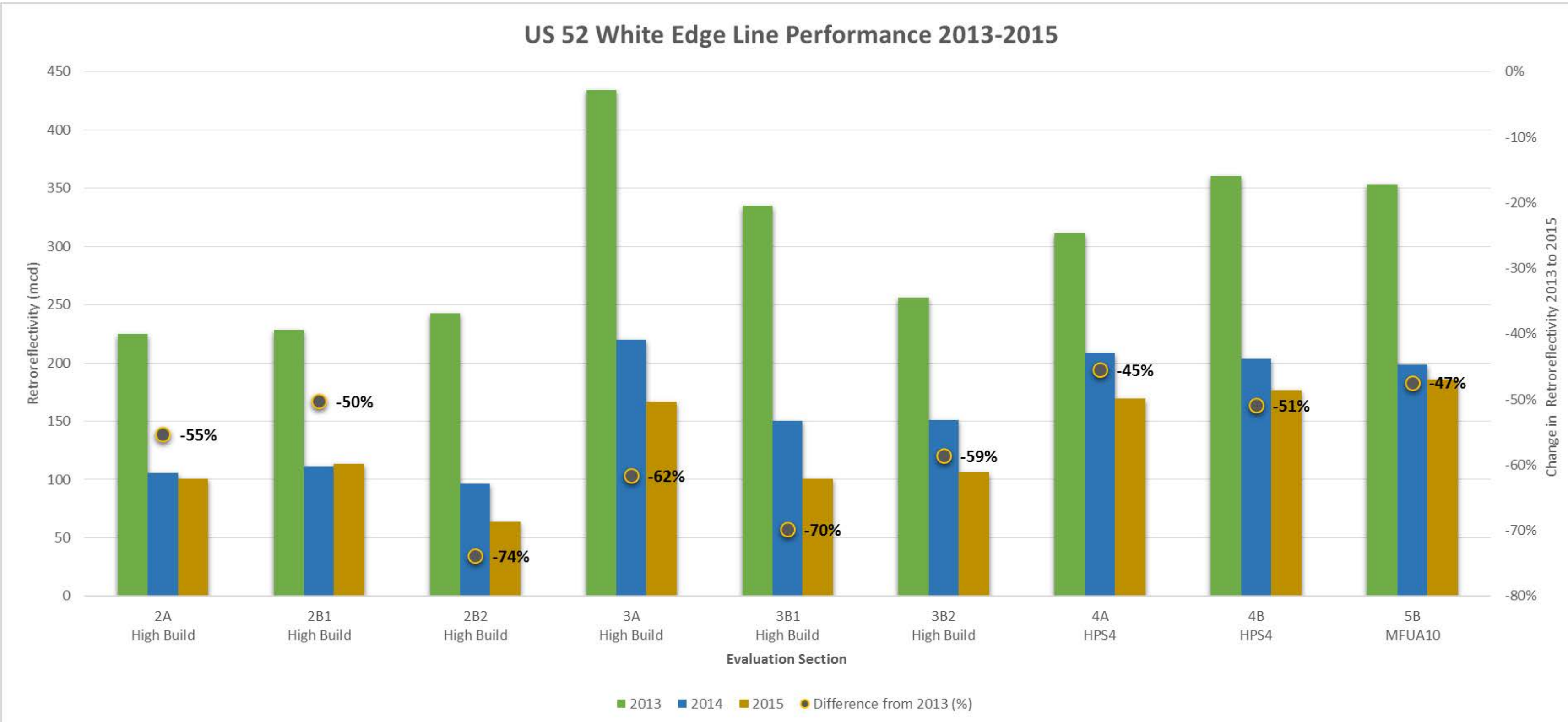


Figure 5-13. US 52 White Edgeline Performance after Two Winters by Test Section

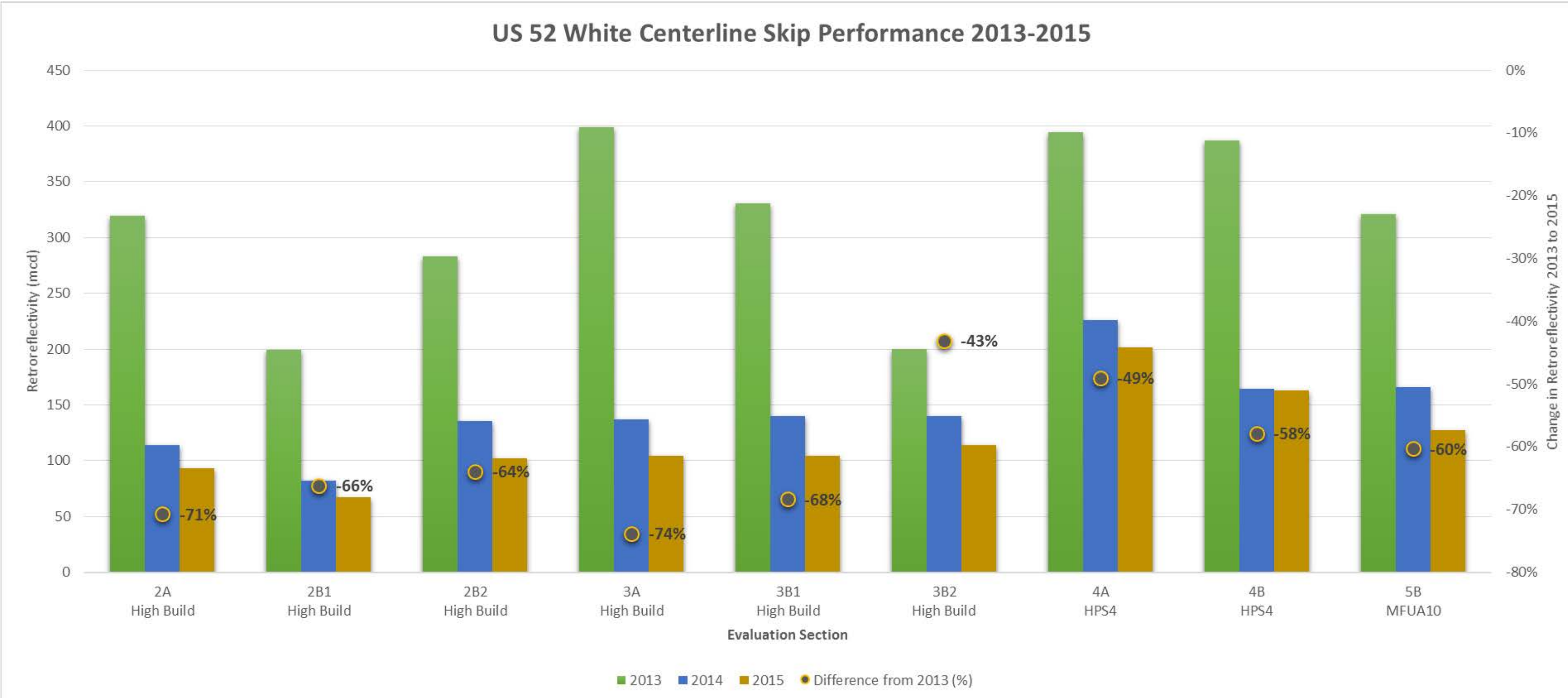


Figure 5-14. US 52 White Centerline Skip Performance after Two Winters by Test Section

5.6.3.3 Pavement Marking Presence

Figure 34 shows an estimate of the percent paint remaining, by US 52 evaluation section and installed materials, after two winters.

						% Paint Remaining (after two winters)	
Section	Material:	Paint Thickness (mil)	Latex Primer:	Reflective Media	Drying Agent	Center Skip Line	Edge Line
2A	High Build	25	Yes	Visiblend		36%	23%
2B-1	High Build	25	No	Visiblend		36%	36%
2B-2	High Build	25	No	Visiblend	Visilok	66%	61%
3A	High Build	35	Yes	Visiblend	Visilok	40%	65%
3B-1	High Build	35	No	Visiblend	Visilok	53%	51%
3B-2	High Build	35	No	Visiblend		69%	61%
4A	HPS4	12	Yes	Std MnDOT		73%	48%
4B	HPS4	12	No	Std MnDOT		47%	48%
5B	MFUA-10	12	No	Std MnDOT		58%	60%

Figure 5-15. US 52 Percent Paint Remaining after Two Winters

The percent paint remaining was measured using image analysis from the available field evaluation images. Only one image was taken per segment and the resulting values should not be considered as a statistically valid sample of the entire section length.

Figure 35 shows pavement marking images in general for each evaluation section of US 52. Following this, additional images for each section after two winters are provided as follows:

Figure 36. US 52 Section 2A

Figure 37. US 52 Section 2B-1 after

Figure 38. US 52 Section 2B-2 after

Figure 39. US 52 Section 3A after

Figure 40. US 52 Section 3B-1 after

Figure 41. US 52 Section 3B-2 after

Figure 42. US 52 Section 4A after

Figure 43. US 52 Section 4B after

Figure 44. US 52 Section 5B after

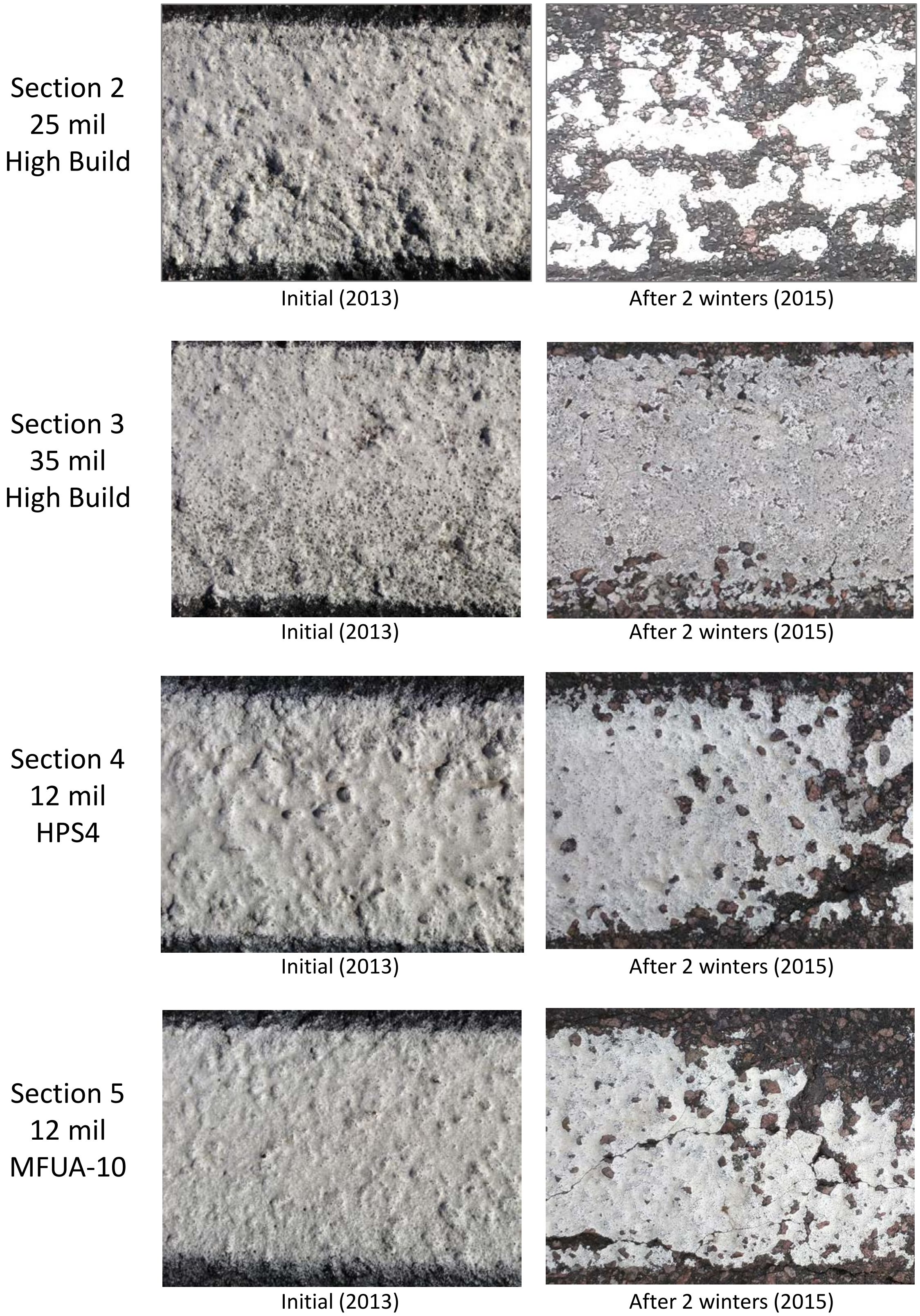


Figure 5-16. US 52 Pavement Marking Presence Initially and after Two Winters

Figure 5-17. US 52 Section 2A after Two Winters

Figure 5-18. US 52 Section 2B-1 after Two Winters

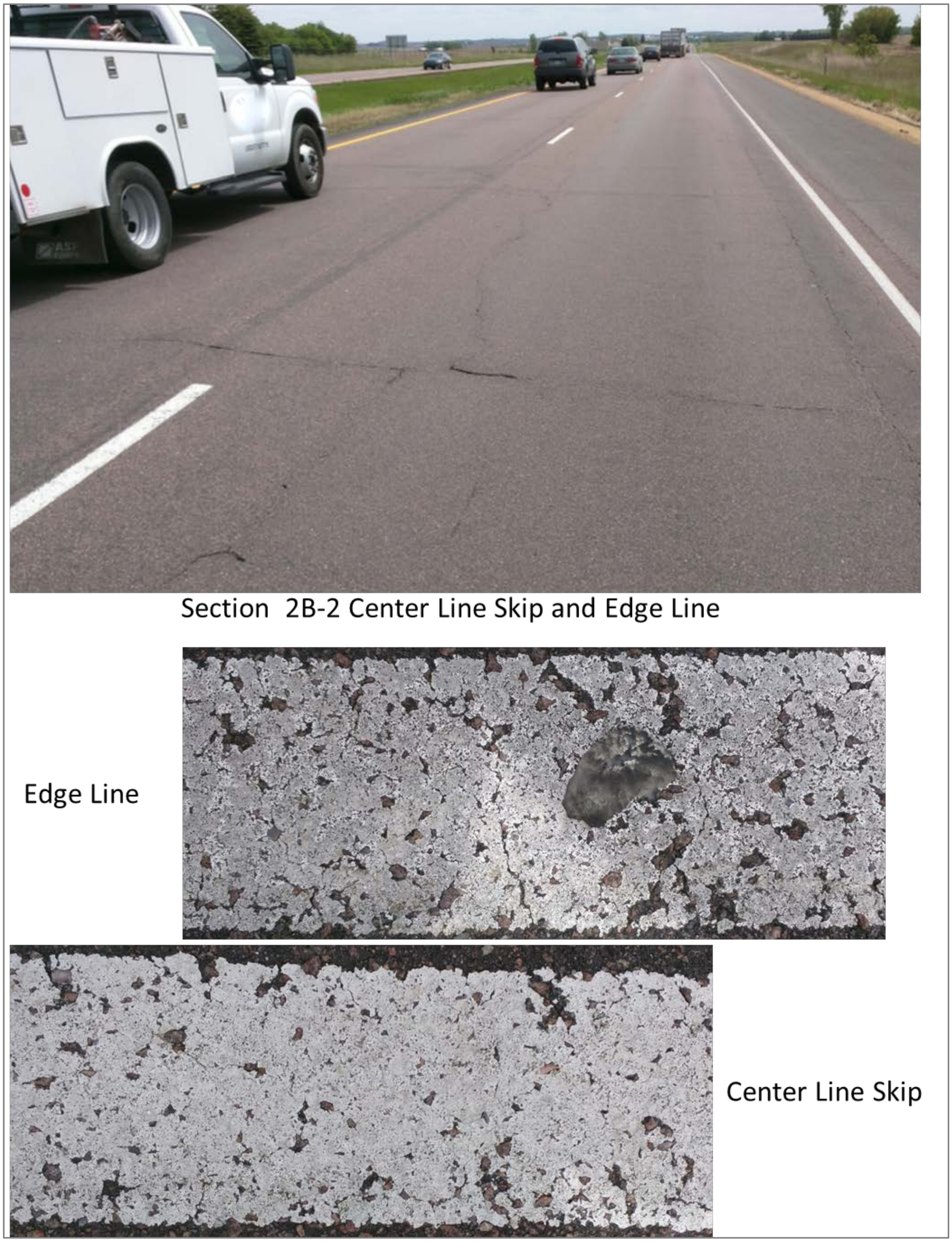


Figure 5-19. US 52 Section 2B-2 after Two Winters

Section 3A Edge Line

Section 3A Center Line Skip

Figure 5-20. US 52 Section 3A after Two Winters

Section 3B-1 Edge Line

Section 3B-1 Center Line Skip

Figure 5-21. US 52 Section 3B-1 after Two Winters

Section 3B-2 Edge Line

Section 3B-2 Center Line Skip

Figure 5-22. US 52 Section 3B-2 after Two Winters

Section 4A Edge Line

Section 4A Center Line Skip

Figure 5-23. US 52 Section 4A after Two Winters

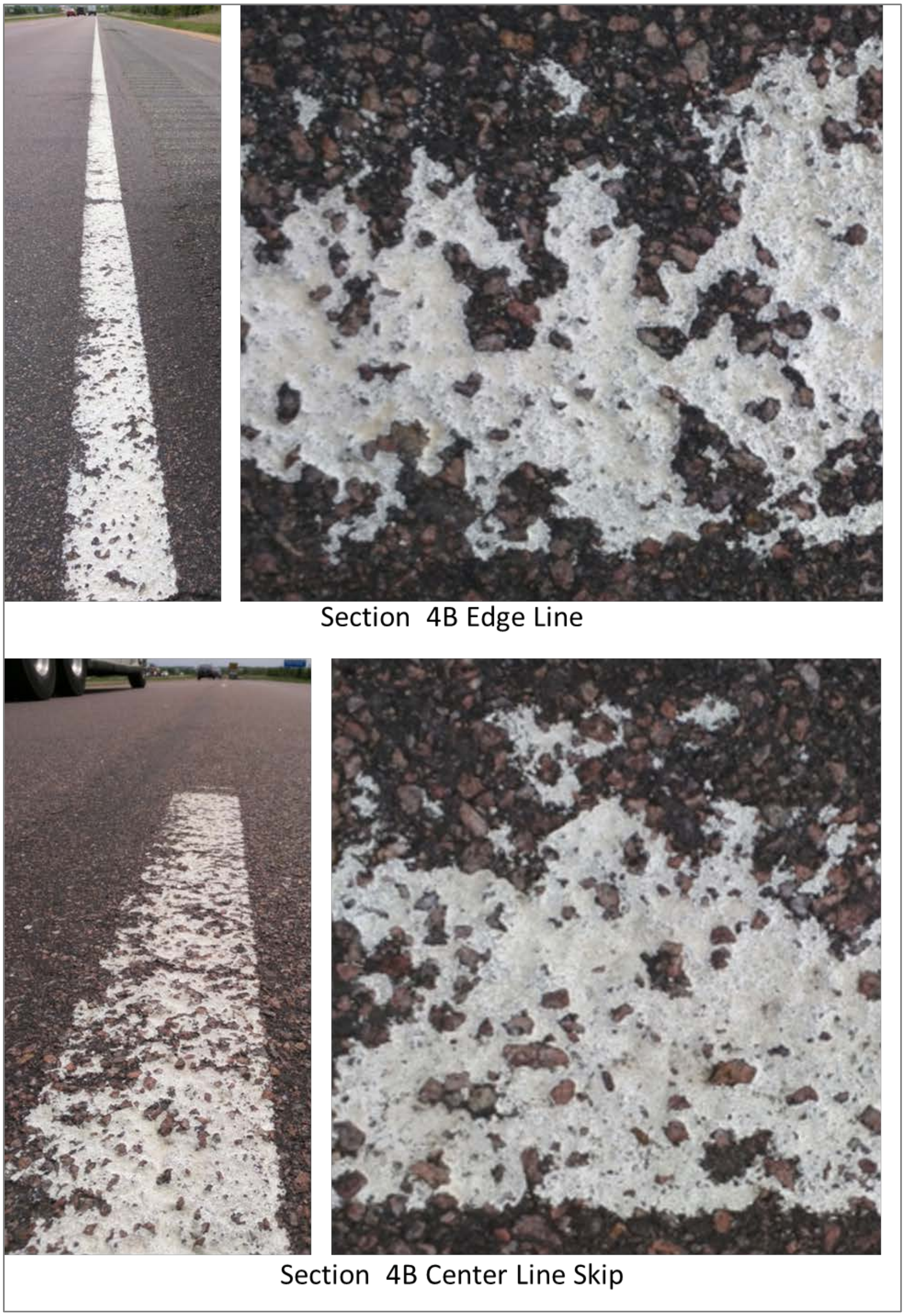


Figure 5-24. US 52 Section 4B after Two Winters

Section 5B Edge Line

Section 5B Center Line Skip

Figure 5-25. US 52 Section 5B after Two Winters

Chapter 6. Conclusions

The objective of this research was to conduct a field trial to evaluate the marking performance of different combinations of pavement marking materials and installation practices on challenging surfaces. The trial included a range of pavement marking products over varied roadway characteristics.

6.1 Existing Practice

The research team worked with the technical advisory panel (TAP) to document pavement marking performance on several municipal roadways within the city of Eden Prairie. These projects provide pavement marking performance on challenging surfaces information over different conditions (traffic levels and line types) apart from the MnDOT research test deck scenarios. Seven different locations were measured, all of which were on seal-coated roadways that were installed in either 2012 or 2013. Based on these field measurements, the following conclusions can be made:

- For yellow centerlines, roadway sections initially painted with latex and epoxy the following year performed (using 100 mcd as a performance threshold) over at least two years and possibly three years, based on traffic and winter maintenance conditions.

- For white edgelines and white skip lines, the data show a difference in performance due to traffic. Section 3 (more than 19,000 vehicles per day) measured 132 mcd after one winter compared to Section 4 (4,400 vehicles per day), which measured 226 mcd. Even though the data are limited, epoxy (applied one year after latex) appears to perform for at least two years and possibly three, depending on traffic and winter maintenance.

- Starting in 2013, the city of Eden Prairie changed its striping practices so that it initially stripes seal-coated roadways with latex paint and then restripes a year later with epoxy. These findings support this practice and show that this can extend the performance of the epoxy stripe up to three years. In discussions with the city, we found that it was replacing epoxy striping after one year on this type of challenging surface.

6.2 Field Evaluation

The research team worked with the project TAP to organize and prepare for field testing of different marking materials on both a seal coat and micro surface roadway. The objective of the field evaluation was to assess the performance of different marking materials over different challenging surfaces by product, thickness, bead package, and whether or not a primer was applied.

The test decks were installed on US 61 and US 52 in August 2013. The US 61 test deck failed due to pavement material issues and was dropped after initial measurements. However, US 52 was measured over two winters. The US 52 evaluation provides the basis for the following conclusions.

- Latex (12 mil thickness) – The two latex sections installed (with and without primer) did not perform and had to be repainted in 2014 (less than one year of performance).

- High build paint – For the 25 mil thickness, the latex primer improved the performance of the pavement marking material. The average for white skip/edgelines was 98 mcd with a primer compared to 83 mcd without. When the material thickness was increased to 35 mil, the primer was not found to have an impact.

- Epoxy – The two epoxy materials used, HPS4 and MFUA-10 (both at 12 mil thickness), provided good performance after two winters regardless of whether a primer was used or not.

- Material thickness – Without the seal-coat test results for US 61, it is not possible to contrast the impact of marking material thicknesses based solely on the micro surface on US 52. However, there is evidence that an increased material thickness improves performance given the results of the 12 mil latex and 25 mil high build. When the material thickness increases above 25 mil, there appears to be enough material to cover the surface voids (resulting from a challenging surface) and still have good performance without a primer.

These results provide MnDOT with a basis to consider pavement marking striping practices on challenging surfaces in terms of performance and cost. The high-build materials (primer plus VISILOK) and epoxies showed similar performance, which provides a good basis for material selection.

Additional work should be completed to evaluate pavement marking performance on seal-coated surfaces given the distinct difference in the surface properties of seal coats versus micro surfacing.